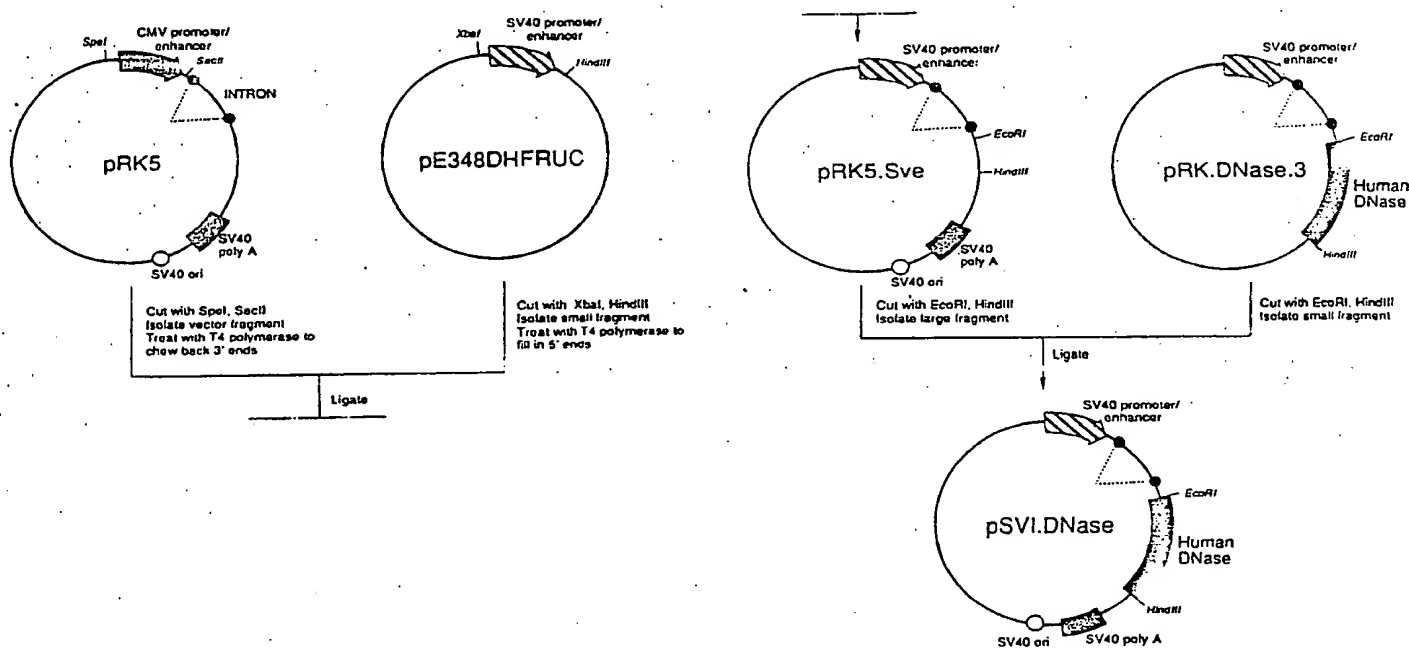




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : C12N 9/16, 15/55	A1	(11) International Publication Number: WO 90/07572 (43) International Publication Date: 12 July 1990 (12.07.90)
(21) International Application Number: PCT/US89/05744 (22) International Filing Date: 20 December 1989 (20.12.89) (30) Priority data: 289,958 23 December 1988 (23.12.88) US 448,038 8 December 1989 (08.12.89) US (71) Applicant: GENENTECH, INC. [US/US]; 460 Point San Bruno Boulevard, South San Francisco, CA 94080 (US). (72) Inventor: SHAK, Steven ; 1133 Cambridge Road, Burlingame, CA 94010 (US). (74) Agents: ADLER, Carolyn, R. et al.; Genentech, Inc., 460 Point San Bruno Boulevard, South San Francisco, CA 94080 (US).		(81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent). Published With international search report.

(54) Title: HUMAN DNase



(57) Abstract

DNA isolates coding for human DNase and methods of obtaining such DNA are provided, together with expression systems for recombinant production of human DNase useful in therapeutic or diagnostic compositions.

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Human DNase..

DNase is a phosphodiesterase capable of hydrolyzing polydeoxyribonucleic acid. It acts to extensively and non-specifically degrade DNA and in this regard is distinguished from the relatively limited and sequence-specific restriction endonucleases. This invention is concerned principally with DNase I and II. DNase I has a pH optimum near neutrality, an obligatory requirement for divalent cations, and produces 5'-phosphate nucleotides on hydrolysis of DNA. DNase II exhibits an acid pH optimum, can be activated by divalent cations and produces 3'-phosphate nucleotides on hydrolysis of DNA. Multiple molecular forms of DNase I and II also are known.

DNase from various species has been purified to varying degree. Bovine DNase A, B, C, and D was purified and completely sequenced as early as 1973 (Liao *et al.*, J. Biol. Chem. 248:1489 [1973]; Salnikow *et al.*, J. Biol. Chem. 248:1499 [1973]; Liao *et al.*, J. Biol. Chem. 249:2354 [1973]). Porcine and ovine DNase have been purified and fully sequenced (Paudel *et al.*, J. Biol. Chem. 261:16006 [1986] and Paudel *et al.*, J. Biol. Chem. 261:16012 [1986]). Human urinary DNase was reported to have been purified to electrophoretically homogeneous state and the N-terminal amino acid observed to be leucine; no other sequence was reported (Ito *et al.*, J. Biochem. 95:1399 [1984]; see also Funakoshi *et al.*, J. Biochem. 82:1771 [1977]; Murai *et al.*, Biochim. et Biophys. Acta 517:186 [1978] and Wroblewski *et al.*, P.S.E.B.M. 74:443 [1950]).

Notwithstanding that full sequence information for a mammalian DNase first became known in 1973, only recently has a report appeared of an attempt to clone and express this class of enzymes. Shields *et al.* describe the expression cloning of part of the gene for bovine DNase I and expression of a fusion product in *E. coli* which was biologically and immunologically active (Biochem. Soc. Trans. 16:195 [1988]). The DNase product of Shields *et al.*, however, was toxic to the host cells and could only be obtained by the use of an inducible promoter. Furthermore, great difficulty was encountered in attempts to isolate plasmid DNA from either clone, an obstacle attributed to constitutive levels of expression of DNase from the clones, so that these authors were unable to determine the sequence for the DNase-encoding nucleic acid. According to Shields *et al.*, the inability to recover the plasmid was the result of constitutive expression of DNase even when the promoter was repressed at low temperature. This would create a considerable obstacle since Shields *et al.* had only identified the clone by expression cloning, which necessarily requires that the DNase be placed under the control of a promoter of some sort.

DNase finds a number of known utilities, and has been used for therapeutic purposes. Its principal therapeutic use has been to reduce the viscosity of pulmonary secretions in such diseases as pneumonia, thereby aiding in the clearing of respiratory airways. Obstruction of airways by secretions can cause respiratory distress, and in some cases, can lead to respiratory failure and death. Bovine pancreatic DNase has been sold under the tradename Dornavac (Merck), but this product was withdrawn from the market. Reports

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indicate that this product had some clinical efficacy. However, although some clinicians observed no significant side effects (Lieberman, JAMA 205:312 [1968]), others noted serious complications such as pulmonary irritation and anaphylaxis (Raskin, Am. Rev. Resp. Dis., 98:697 [1968]). Such complications may be attributed to the fact that the previously marketed products were contaminated with proteases and were immunogenic in humans. In fact, although the clinical problem of thick pulmonary secretions is often chronic and recurring, prolonged therapy with bovine pancreatic DNase was not recommended. These problems could be overcome by providing DNase of human origin and producing it in large quantities in nonpancreatic exocrine cells to facilitate purification free of contaminant proteases.

Accordingly, it is an object of this invention to provide nucleic acid encoding human DNase.

It is another object to provide a method for expression of human DNase in recombinant cell culture.

A further object is to enable the preparation of DNase having variant amino acid sequences or glycosylation not otherwise found in nature, as well as other derivatives of DNase, having improved properties including enhanced specific activity.

The objects of this invention have been accomplished by a method comprising providing nucleic acid encoding human DNase; transforming a host cell with the nucleic acid; culturing the host cell to allow DNase to accumulate in the culture; and recovering DNase from the culture. Surprisingly, a full length clone encoding human DNase has been identified and recovered, and moreover this DNA is readily expressed by recombinant host cells.

In preferred embodiments the mammalian DNase is full-length, mature human DNase, having the amino acid sequence of native human DNase, its naturally occurring alleles, or predetermined amino acid sequence or glycosylation variants thereof. The nucleic acid encoding the DNase preferably encodes a preprotein which is processed and secreted from host cells, particularly mammalian cells.

Figure 1 depicts the amino acid and DNA sequence of human DNase. The native signal sequence is underlined, the potential initiation codons are circled, and the mature sequence is bracketed.

Figure 2 shows a comparison between the amino acid sequence for mature human (hDNase) and bovine (bDNase) DNase. Asterisks denominate exact homology, periods designate conserved substitutions.

Figure 3 shows the construction of the expression vectors pRK.DNase.3 and pSVe.DNase.

Figure 4 shows the construction of the expression vector pSVI.DNase that contains the splice unit of the pRK5 vector without any modifications.

Figure 5 shows the construction of the expression vectors pSVI12.DNase, pSVI13.DNase, pSVI15.DNase, and pSVI16b.DNase containing the modifications in the splice unit and surrounding DNA.

Figure 6 shows the complete nucleotide sequence of pSVI.DNase up to, but not including, the coding region of DNase.

Figure 7 shows the complete nucleotide sequence of pSVI2.DNase up to, but not including, the coding region of DNase.

5 Figure 8 shows the complete nucleotide sequence of pSVI3.DNase up to, but not including, the coding region of DNase.

Figure 9 shows the complete nucleotide sequence of pSVI5.DNase up to, but not including, the coding region of DNase.

10 Figure 10 shows the complete nucleotide sequence of pSVI6B.DNase up to, but not including, the coding region of DNase.

Fig. 11 shows a schematic representation of the splice unit nucleotide sequences involved in the preparation of the vectors of this example, i.e., SVI, SVI2, SVI3, SVI5, and SVI6B. The boxes represent changes from the SVI sequence, the double underlining is a spurious ATG codon, the underlining shows spurious splice sites and added or changed branchpoint sequence (BPS) regions, the breaks in sequence represent deletions of the nucleotides for SVI3-SVI5, the "..." designation indicates sequence not shown, and the carets indicate the 5' and 3' cleavage sites within the splice donor and splice acceptor, respectively, of the splice unit.

20 Human DNase is defined as a polypeptide having the amino acid sequence of Fig. 1 together with amino acid sequence variants thereof which retain the qualitative enzymatic activity of DNase. Preferably, the variants are not immunogenic in humans. Variants may possess greater enzymatic activity, enhanced resistance to inhibition (in particular by actin), improved solubility, or may be expressed at higher levels by host cells.

25 Amino acid sequence variants of DNase fall into one or more of three classes: Substitutional, insertional or deletional variants. These variants ordinarily are prepared by site specific mutagenesis of nucleotides in the DNA encoding the DNase, by which DNA encoding the variant is obtained, and thereafter expressing the DNA in recombinant cell culture. However, variant DNase fragments having up to about 100-150 residues may be prepared conveniently by *in vitro* synthesis.

30 The amino acid sequence variants of human DNase are predetermined or are naturally occurring alleles. For example, bovine pancreatic DNase is found naturally as 4 molecular variants which possess the same enzymatic activity but differ in glycosylation pattern or substitution at the amino acid level. Additionally, human DNase is found naturally with an arginine or a glutamine residue at amino acid 222. The variants typically exhibit the same qualitative biological activity as the naturally-occurring analogue. Specifically excluded from the scope of human DNase as described herein are the sequences of naturally occurring bovine, porcine or ovine DNase.

35 While the site for introducing an amino acid sequence variation is predetermined, the mutation *per se* need not be predetermined. For example, in order to optimize the performance of a mutation at a given site, saturation mutagenesis is introduced at the target

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codon or region and the DNase variants then screened for the optimal combination of desired activity.

Amino acid substitutions are typically introduced for single residues; insertions usually will be on the order of about from 1 to 10 amino acid residues; and deletions will range about from 1 to 30 residues. Deletions or insertions preferably are made in adjacent pairs, i.e. a deletion of 2 residues or insertion of 2 residues. Substitutions, deletions, insertions or any combination thereof may be combined to arrive at a final construct. Obviously, the mutations that will be made in the DNA encoding the variant DNase must not place the sequence out of reading frame and preferably will not create complementary regions that could produce secondary mRNA structure (EP 75,444A).

Substitutional variants are those in which at least one residue in the Fig. 1 sequence has been removed and a different residue inserted in its place. Such substitutions generally are made in accordance with the following Table 1 when it is desired to finely modulate the characteristics of DNase.

TABLE 1

Original Residue	Exemplary Substitutions
Ala	ser
Arg	lys
Asn	gln; his
Asp	glu
Cys	ser
Gln	asn
Glu	asp
Gly	pro
His	asn; gln
Ile	leu; val
Leu	ile; val
Lys	arg; gln; glu
Met	leu; ile
Phe	met; leu; tyr
Ser	thr
Thr	ser
Trp	tyr
Tyr	trp; phe
Val	ile; leu

Substantial changes in function or immunological identity are made by selecting substitutions that are less conservative than those in Table 1, i.e., selecting residues that differ more significantly in their effect on maintaining (a) the structure of the polypeptide backbone in the area of the substitution, for example as a sheet or helical conformation, (b) the charge or hydrophobicity of the molecule at the target site or (c) the bulk of the side chain. The substitutions which in general are expected to produce the greatest changes in

DNase properties will be those in which (a) a hydrophilic residue, e.g. seryl or threonyl, is substituted for (or by) a hydrophobic residue, e.g. leucyl, isoleucyl, phenylalanyl, valyl or alanyl; (b) a cysteine or proline is substituted for (or by) any other residue; (c) a residue having an electropositive side chain, e.g., lysyl, arginyl, or histidyl, is substituted for (or by) an electronegative residue, e.g., glutamyl or aspartyl; or (d) a residue having a bulky side chain, e.g., phenylalanine, is substituted for (or by) one not having a side chain, e.g., glycine.

Examples of human DNase amino acid sequence variants are described in the table below. The residue following the residue number indicates the replacement or inserted amino acids.

Table 2

<u>Substitutions</u>	
H134K, N, R or Q	FGW, L, I, M or V
A135S	I8F, L, V, M or W
L133V, I or A	R41K or H
P132A	S43T, C or Y
N18K, H, R or Q	K77R or H
S17T	R79K or H
T20S or Y	N110D, S, T, R, Y or Q
N106K, H, R or Q	G167P
G105P or A	F169L, V, I or M
D107E or T	A171G, V or M
R140A	S250T, Y or M
R121K or H	Y253T, S or M
T108S or Y	R73N
P103S, T or Y	R73C + D139C
C101S, T, Y or M	K260R or S
C104S, T, Y or M	L259V, I or M
<u>Deletions</u>	<u>Insertions</u>
Δ34H-Δ39E	K260RA-COOH
Δ159G-161E	V131A P132
Δ204A-208H	P132A L133
Δ121R-127E	
Δ188T-191T	
Δ204A-208H	
Δ223G-231L	
Δ260K	

In general, sequence variation is introduced into residues 6-10, 41-43, 77-79, 110-112, 167-171, 250-253, 73, 93, 157, 149, 185, 187, 198, 17-20, 105-108 and 131-139. Preferably, the variants represent conservative substitutions. It will be understood that some variants may exhibit reduced or absent hydrolytic activity. These variants nonetheless are useful as standards in immunoassays for DNase so long as they retain at least one immune epitope of native human DNase.

Glycosylation variants are included within the scope of human DNase. Included are unglycosylated amino acid sequence variants, unglycosylated DNase having the native, unmodified amino acid sequence of DNase, and glycosylation variants. For example,

substitutional or deletional mutagenesis is employed to eliminate the N-linked glycosylation sites of human DNase found at residues 18 and 106, e.g., the asparagine residue is deleted or substituted for by another basic residue such as lysine or histidine. Alternatively, flanking residues making up the glycosylation site are substituted or deleted, even though the asparagine residues remain unchanged, in order to prevent glycosylation by eliminating the glycosylation recognition site. Unglycosylated DNase which has the amino acid sequence of native human DNase is produced in recombinant prokaryotic cell culture because prokaryotes are incapable of introducing glycosylation into polypeptides. In addition, glycosylation variants may be generated by adding potential N-linked glycosylation sites through inserting (either by amino acid substitution or deletion) consensus sequences for N-linked glycosylation: Asn-X-Ser or Asn-X-Thr. Glycosylation variants may be generated by both eliminating the N-linked glycosylation sites at residues 18 and 106 and by adding new ones.

Glycosylation variants, i.e., glycosylation which is different from that of human pancreatic or urinary DNase, are produced by selecting appropriate host cells or by *in vitro* methods. Yeast, for example, introduce glycosylation which varies significantly from that of mammalian systems. Similarly, mammalian cells having a different species (e.g. hamster, murine, insect, porcine, bovine or ovine) or tissue origin (e.g. lung, liver, lymphoid, mesenchymal or epidermal) than the source of the DNase are screened for the ability to introduce variant glycosylation as characterized for example by elevated levels of mannose or variant ratios of mannose, fucose, sialic acid, and other sugars typically found in mammalian glycoproteins. In addition, mammalian or yeast cells which possess mutations with respect to glycosylation phenotype may be identified, selected for following mutation, or constructed and utilized to produce DNase. *In vitro* processing of DNase typically is accomplished by enzymatic hydrolysis, e.g. neuraminidase or endoglycosydase H digestion.

Insertional amino acid sequence variants of DNases are those in which one or more amino acid residues are introduced into a predetermined site in the target DNase and which displace the preexisting residues. Most commonly, insertional variants are fusions of heterologous proteins or polypeptides to the amino or carboxyl terminus of DNase. DNase derivatives which are immunogenic in humans are not preferred, e.g. those which are made by fusing an immunogenic polypeptide to DNase by cross-linking *in vitro* or by recombinant cell culture transformed with DNA encoding immunogenic fusions such as lacZ. For this reason, the typical insertional variants contemplated herein are the signal sequence variants described above.

Covalent modifications of the DNase molecule are included within the scope hereof. Such modifications are introduced by reacting targeted amino acid residues of the recovered protein with an organic derivatizing agent that is capable of reacting with selected side chains or terminal residues, or by harnessing mechanisms of post-translational modification that function in selected recombinant host cells. The resulting covalent derivatives are useful in programs directed at identifying residues important for biological activity, for immunoassays of DNase or for the preparation of anti-human DNase antibodies for

immunoaffinity purification of recombinant DNase. For example, complete inactivation of the biological activity of the protein after reaction with ninhydrin would suggest that at least one arginyl or lysyl residue is critical for its activity, whereafter the individual residues which were modified under the conditions selected are identified by isolation of a peptide fragment containing the modified amino acid residue.

Cysteiny residues most commonly are reacted with α -haloacetates (and corresponding amines), such as chloroacetic acid or chloroacetamide to give carboxymethyl or carboxamidomethyl derivatives. Cysteiny residues also are derivatized by reaction with bromotrifluoroacetone, α -bromo- β -(5-imidazolyl) propionic acid, chloroacetol phosphate, N-alkylmaleimides, 3-nitro-2-pyridyl disulfide, methyl 2-pyridyl disulfide, p-chloromercuribenzoate, 2-chloromercuri-4-nitrophenol or chloro-7-nitrobenzo-2-oxa-1,3-diazole.

Histidyl residues preferably are derivatized by reaction with diethylpyrocarbonate at pH 5.5 to 7.0 because this agent is relatively specific for the histidyl side chain. Para-bromo-phenacyl bromide also is useful; the reaction should be performed in 0.1M sodium cacodylate at pH 6.0.

Lysiny and amino terminal residues are reacted with succinic or other carboxylic acid anhydrides. Derivatization with these agents has the effect of reversing the charge of the lysiny residues. Other suitable reagents for derivatizing α amino-containing residues include imidoesters such as methyl picolinimide; pyridoxal phosphate; pyridoxal; chloroborohydride; trinitrobenzenesulfonic acid; O-methylisourea; 2,4-pentanedione; and transaminase-catalyzed reaction with glyoxylate.

Arginy residues are modified by reaction with one of several conventional reagents, among them phenylglyoxal, 2,3-butanedione, 1,2-cyclohexanedione, and ninhydrin. Derivatization of arginine residues requires that the reaction be performed in alkaline conditions because of the high pKa of the guanidine functional group. Furthermore, these reagents may react with the groups of lysine as well as the arginine ϵ -amino group.

The specific modification of tyrosyl residues *per se* has been extensively studied, with particular interest in introducing spectral labels into tyrosyl residues by reaction with aromatic diazonium compounds or tetranitromethane. Most commonly, N-acetylimidizol and tetranitromethane are used to form O-acetyl tyrosyl species and 3-nitro derivatives, respectively. Tyrosyl residues are iodinated using ^{125}I or ^{131}I to prepare labelled proteins for use in radioimmunoassay, the chloramine T method being widely adopted *per se* for this purpose.

Carboxyl side groups (aspartyl or glutamyl) are selectively modified by reaction with carbodiimides ($\text{R}'\text{-N}=\text{C}=\text{N}-\text{R}'$) such as 1-cyclohexyl-3-(2-morpholinyl)-(4)-ethyl carbodiimide or 1-ethyl-3-(4-azonia-4,4-dimethylpentyl)-carbodiimide. Furthermore, aspartyl and glutamyl residues are converted to asparaginy and glutaminy residues by reaction with ammonium ions, this being an alternative to mutating the nucleic acid to encode asparagine or glutamine.

Derivatization with bifunctional agents is useful for preparing intermolecular aggregates of the protein with immunogenic polypeptides as well as for cross-linking the protein to a water insoluble support matrix or surface for use in the assay or affinity purification of antibody. In addition, a study of intrachain cross-links will provide direct information on conformational structure. Commonly used cross-linking agents include 1,1-bis(diazoacetyl)-2-phenylethane, glutaraldehyde, N-hydroxysuccinimide esters, for example esters with 4-azidosalicylic acid, homobifunctional imidoesters including disuccinimidyl esters such as 3,3'-dithiobis (succinimidyl-propionate), and bifunctional maleimides such as bis-N-maleimido-1,8-octane. Derivatizing agents such as methyl-3-[(p-azido-phenyl)dithio] propioimide yield photoactivatable intermediates which are capable of forming cross-links in the presence of light. Alternatively, reactive water insoluble matrices such as cyanogen bromide activated carbohydrates and the reactive substrates described in U.S. patents 3,969,287; 3,691,016; 4,195,128; 4,247,642; 4,229,537 and 4,330,440 are employed for protein immobilization.

Certain post-translational derivatizations are the result of the action of recombinant host cells on the expressed polypeptide. Glutaminyl and asparaginyl residues are frequently post-translationally deamidated to the corresponding glutamyl and aspartyl residues. Alternatively, these residues are deamidated under mildly acidic conditions. Either form of these residues falls within the scope of this invention.

Other post-translational modifications include hydroxylation of proline and lysine, phosphorylation of hydroxyl groups of seryl or threonyl residues, methylation of the α -amino groups of lysine, arginine, and histidine side chains (T.E. Creighton, Proteins: Structure and Molecular Properties, W.H. Freeman & Co., San Francisco pp 79-86 [1983]), acetylation of the N-terminal amine and, in some instances, amidation of the C-terminal carboxyl.

Other derivatives comprise the polypeptide of this invention covalently bonded to a nonproteinaceous polymer. The nonproteinaceous polymer ordinarily is a hydrophilic synthetic polymer, i.e., a polymer not otherwise found in nature. However, polymers which exist in nature and are produced by recombinant or *in vitro* methods are useful, as are polymers which are isolated from nature. Hydrophilic polyvinyl polymers fall within the scope of this invention, e.g. polyvinylalcohol and polyvinylpyrrolidone. Particularly useful are polyalkylene ethers such as polyethylene glycol, polypropylene glycol, polyoxyethylene esters or methoxy polyethylene glycol; polyoxyalkylenes such as polyoxyethylene, polyoxypropylene, and block copolymers of polyoxyethylene and polyoxypropylene (Pluronic); polymethacrylates; carbomers; branched or unbranched polysaccharides which comprise the saccharide monomers D-mannose, D- and L-galactose, fucose, fructose, D-xylose, L-arabinose, D-glucuronic acid, sialic acid, D-galacturonic acid, D-mannuronic acid (e.g. polymannuronic acid, or alginic acid), D-glucosamine, D-galactosamine, D-glucose and neuraminic acid including homopolysaccharides and heteropolysaccharides such as lactose, amylopectin, starch, hydroxyethyl starch, amylose, dextran sulfate, dextran, dextrans, glycogen, or the polysaccharide subunit of acid mucopolysaccharides, e.g.

hyaluronic acid; polymers of sugar alcohols such as polysorbitol and polymannitol; and heparin or heparan. Where the polysaccharide is the native glycosylation or the glycosylation attendant on recombinant expression, the site of substitution may be located at other than a native N or O-linked glycosylation site wherein an additional or substitute N or O-linked site has been introduced into the molecule. Mixtures of such polymers are employed, or the polymer may be homogeneous. The polymer prior to crosslinking need not be, but preferably is, water soluble, but the final conjugate must be water soluble. In addition, the polymer should not be highly immunogenic in the conjugate form, nor should it possess viscosity that is incompatible with intravenous infusion or injection if it is intended to be administered by such routes.

Preferably the polymer contains only a single group which is reactive. This helps to avoid cross-linking of protein molecules. However, it is within the scope herein to optimize reaction conditions to reduce cross-linking, or to purify the reaction products through gel filtration or chromatographic sieves to recover substantially homogeneous derivatives.

The molecular weight of the polymer ranges about from 100 to 500,000, and preferably is about from 1,000 to 20,000. The molecular weight chosen will depend upon the nature of the polymer and the degree of substitution. In general, the greater the hydrophilicity of the polymer and the greater the degree of substitution, the lower the molecular weight that can be employed. Optimal molecular weights will be determined by routine experimentation.

The polymer generally is covalently linked to the polypeptide herein through a multifunctional crosslinking agent which reacts with the polymer and one or more amino acid or sugar residues of the protein. However, it is within the scope of this invention to directly crosslink the polymer by reacting a derivatized polymer with the protein, or vice versa.

The covalent crosslinking site on the polypeptide includes the N-terminal amino group and epsilon amino groups found on lysine residues, as well as other amino, imino, carboxyl, sulfhydryl, hydroxyl or other hydrophilic groups. The polymer may be covalently bonded directly to the protein without the use of a multifunctional (ordinarily bifunctional) crosslinking agent. Examples of such crosslinking agents include 1,1-bis(diazoacetyl)-2-phenylethane, glutaraldehyde, N-hydroxysuccinimide esters, for example esters with 4-azidosalicylic acid, homobifunctional imidoesters including disuccinimidyl esters such as 3,3'-dithiobis (succinimidyl-propionate), and bifunctional maleimides such as bis-N-maleimido-1,8-octane. Derivatizing agents such as methyl-3-[(p-azido-phenyl)dithio]propioimide yield photoactivatable intermediates which are capable of forming cross-links in the presence of light. Alternatively, reactive water soluble matrices such as cyanogen bromide activated carbohydrates and the systems described in U.S. patents 3,959,080; 3,969,287; 3,691,016; 4,195,128; 4,247,642; 4,229,537; 4,055,635 and 4,330,440 are suitably modified for cross-linking. Covalent bonding to amino groups is accomplished by known chemistries based upon cyanuric chloride, carbonyl diimidazole, aldehyde reactive groups (PEG alkoxide plus diethyl acetal of bromoacetaldehyde; PEG plus DMSO

and acetic anhydride, or PEG chloride plus the phenoxide of 4-hydroxybenzaldehyde, succinimidyl active esters, activated dithiocarbonate PEG, 2,4,5-trichlorophenylchloroformate or p-nitrophenylchloroformate activated PEG. Carboxyl groups are derivatized by coupling PEG-amine using carbodiimide.

5 Polymers are conjugated to oligosaccharide groups by oxidation using chemicals, e.g. metaperiodate, or enzymes, e.g. glucose or galactose oxidase, (either of which produces the aldehyde derivative of the carbohydrate), followed by reaction with hydrazide or amino-derivatized polymers, in the same fashion as is described by Heitzmann *et al.*, P.N.A.S., 71:3537-3541 (1974) or Bayer *et al.*, Methods in Enzymology, 62:310 (1979), for the labeling
10 of oligosaccharides with biotin or avidin. Further, other chemical or enzymatic methods which have been used heretofore to link oligosaccharides and polymers may be suitable. Substituted oligosaccharides are particularly advantageous because, in general, there are fewer substitutions than amino acid sites for derivatization, and the oligosaccharide products thus will be more homogeneous. The oligosaccharide substituents also are optionally
15 modified by enzyme digestion to remove sugars, e.g. by neuraminidase digestion, prior to polymer derivatization.

 The polymer will bear a group which is directly reactive with an amino acid side chain, or the N- or C- terminus of the polypeptide herein, or which is reactive with the multifunctional cross-linking agent. In general, polymers bearing such reactive groups are
20 known for the preparation of immobilized proteins. In order to use such chemistries here, one should employ a water soluble polymer otherwise derivatized in the same fashion as insoluble polymers heretofore employed for protein immobilization. Cyanogen bromide activation is a particularly useful procedure to employ in crosslinking polysaccharides.

 "Water soluble" in reference to the polymer conjugate means that the conjugate is
25 soluble in physiological fluids such as blood in an amount which is sufficient to achieve a therapeutically effective concentration.

 "Water soluble" in reference to the starting polymer means that the polymer or its reactive intermediate used for conjugation is sufficiently water soluble to participate in a derivatization reaction.

30 The degree of substitution with polymer will vary depending upon the number of reactive sites on the protein, whether all or a fragment of protein is used, whether the protein is a fusion with a heterologous protein, the molecular weight, hydrophilicity and other characteristics of the polymer, and the particular protein derivatization sites chosen. In general, the conjugate contains about from 1 to 10 polymer molecules, while any
35 heterologous sequence may be substituted with an essentially unlimited number of polymer molecules so long as the desired activity is not significantly adversely affected. The optimal degree of crosslinking is easily determined by an experimental matrix in which the time, temperature and other reaction conditions are varied to change the degree of substitution, after which the ability of the conjugates to function in the desired fashion is determined.

40 The polymer, e.g. PEG, is crosslinked by a wide variety of methods known *per se* for the covalent modification of proteins with nonproteinaceous polymers such as PEG. Certain

of these methods, however, are not preferred for the purposes herein. Cyanuric chloride chemistry leads to many side reactions, including protein cross-linking. In addition, it may be particularly likely to lead to inactivation of proteins containing sulfhydryl groups. Carbonyl diimidazole chemistry (Beauchamp *et al.*, "Anal. Biochem." 131:25-33 [1983]) requires high pH (>8.5), which can inactivate proteins. Moreover, since the "activated PEG" intermediate can react with water, a very large molar excess of "activated PEG" over protein is required. The high concentrations of PEG required for the carbonyl diimidazole chemistry also led to problems with purification, as both gel filtration chromatography and hydrophobic interaction chromatography are adversely effected. In addition, the high concentrations of "activated PEG" may precipitate protein, a problem that *per se* has been noted previously (Davis, U.S. Patent 4,179,337). On the other hand, aldehyde chemistry (Royer, U.S. Patent 4,002,531) is more efficient since it requires only a 40 fold molar excess of PEG and a 1-2 hr incubation. However, the manganese dioxide suggested by Royer for preparation of the PEG aldehyde is problematic "because of the pronounced tendency of PEG to form complexes with metal-based oxidizing agents" (Harris *et al.*, "J. Polym. Sci., Polym. Chem. Ed." 22:341-352 [1984]). The use of a Moffatt oxidation, utilizing DMSO and acetic anhydride, obviates this problem. In addition, the sodium borohydride suggested by Royer must be used at a high pH and has a significant tendency to reduce disulfide bonds. In contrast, sodium cyanoborohydride, which is effective at neutral pH and has very little tendency to reduce disulfide bonds is preferred.

The conjugates of this invention are separated from unreacted starting materials by gel filtration. Heterologous species of the conjugates are purified from one another in the same fashion. The polymer also may be water insoluble, as a hydrophilic gel or a shaped article. Particularly useful are polymers comprised by surgical tubing such as catheters or drainage conduits.

DNA encoding human DNase is synthesized by *in vitro* methods or is obtained readily from human pancreatic cDNA libraries. Since Fig. 1 gives the entire DNA sequence for human DNase, one needs only to conduct hybridization screening with labelled DNA encoding human DNase or fragments thereof (usually, greater than about 50bp) in order to detect clones in the cDNA libraries which contain homologous sequences, followed by analyzing the clones by restriction enzyme analysis and nucleic acid sequencing to identify full-length clones. If full length clones are not present in the library, then appropriate fragments may be recovered from the various clones and ligated at restriction sites common to the fragments to assemble a full-length clone. DNA encoding DNase from other animal species is obtained by probing libraries from such species with the human sequence, or by synthesizing the genes *in vitro* (for bovine, porcine or ovine DNase).

Included within the scope hereof are nucleic acid probes which are capable of hybridizing under high stringency conditions to the cDNA of human DNase or to the genomic gene for human DNase (including introns and 5' or 3' flanking regions extending to the adjacent genes or about 5,000 bp, whichever is greater). Identification of the genomic DNA for DNase is a straight-forward matter of probing a human genomic library

with the cDNA or its fragments which have been labelled with a detectable group, e.g. radiophosphorus, and recovering clone(s) containing the gene. The complete gene is pieced together by "walking" if necessary. Typically, the probes do not encode bovine, ovine or porcine DNase, and they range about from 10 to 100 bp in length.

5 In general, prokaryotes are used for cloning of DNA sequences in constructing the vectors useful in the invention. For example, *E. coli* K12 strain 294 (ATCC No. 31446) is particularly useful. Other microbial strains which may be used include *E. coli* B and *E. coli* X1776 (ATCC No. 31537). These examples are illustrative rather than limiting. Alternatively, *in vitro* methods of cloning, e.g., PCR, are suitable.

10 DNase is expressed directly in recombinant cell culture as an N-terminal methionyl analogue, or as a fusion with a polypeptide heterologous to human DNase, preferably a signal sequence or other polypeptide having a specific cleavage site at the N-terminus of the DNase. For example, in constructing a prokaryotic secretory expression vector the native DNase signal is employed with hosts that recognize the human signal. When the
15 secretory leader is "recognized" by the host, the host signal peptidase is capable of cleaving a fusion of the leader polypeptide fused at its C-terminus to the desired mature DNase. For host prokaryotes that do not process the human signal, the signal is substituted by a prokaryotic signal selected for example from the group of the alkaline phosphatase, penicillinase, lpp or heat stable enterotoxin II leaders. For yeast secretion the human DNase
20 signal may be substituted by the yeast invertase, alpha factor or acid phosphatase leaders. In mammalian cell expression the native signal is satisfactory, although other mammalian secretory protein signals are suitable, as are viral secretory leaders, for example the herpes simplex gD signal.

DNase is expressed in any host cell, but preferably is synthesized in mammalian hosts.
25 However, host cells from prokaryotes, fungi, yeast, pichia, insects and the like are also used for expression. Exemplary prokaryotes are the strains suitable for cloning as well as *E. coli* W3110 (F⁻, λ ⁻ prototrophic, ATCC No. 27325), other enterobacteriaceae such as Serratia marcescans, bacilli and various pseudomonads. Preferably the host cell should secrete minimal amounts of proteolytic enzymes.

30 Expression hosts typically are transformed with DNA encoding human DNase which has been ligated into an expression vector. Such vectors ordinarily carry a replication site (although this is not necessary where chromosomal integration will occur). It is presently preferred to utilize an expression vector as described in Example 4 below, where the vector contains a splice-donor-intron-splice-acceptor sequence or unit.

35 Expression vectors also include marker sequences which are capable of providing phenotypic selection in transformed cells. For example, *E. coli* is typically transformed using pBR322, a plasmid derived from an *E. coli* species (Bolivar, *et al.*, Gene 2: 95 [1977]). pBR322 contains genes for ampicillin and tetracycline resistance and thus provides easy means for identifying transformed cells, whether for purposes of cloning or expression.
40 Expression vectors also optimally will contain sequences which are useful for the control of transcription and translation, e.g., promoters and Shine-Dalgarno sequences (for

prokaryotes) or promoters and enhancers (for mammalian cells). The promoters may be, but need not be, inducible; surprisingly, even powerful constitutive promoters such as the CMV promoter for mammalian hosts have been found to produce DNase without host cell toxicity. While it is conceivable that expression vectors need not contain any expression control, replicative sequences or selection genes, their absence may hamper the identification of DNase transformants and the achievement of high level DNase expression.

Promoters suitable for use with prokaryotic hosts illustratively include the β -lactamase and lactose promoter systems (Chang *et al.*, "Nature", 275: 615 [1978]; and Goeddel *et al.*, "Nature" 281: 544 [1979]), alkaline phosphatase, the tryptophan (trp) promoter system (Goeddel "Nucleic Acids Res." 8: 4057 [1980] and EPO Appln. Publ. No. 36,776) and hybrid promoters such as the tac promoter (H. de Boer *et al.*, "Proc. Natl. Acad. Sci. USA" 80: 21-25 [1983]). However, other functional bacterial promoters are suitable. Their nucleotide sequences are generally known, thereby enabling a skilled worker operably to ligate them to DNA encoding DNase (Siebenlist *et al.*, "Cell" 20: 269 [1980]) using linkers or adaptors to supply any required restriction sites. Promoters for use in bacterial systems also will contain a Shine-Dalgarno (S.D.) sequence operably linked to the DNA encoding DNase.

In addition to prokaryotes, eukaryotic microbes such as yeast, or filamentous fungi are satisfactory. Saccharomyces cerevisiae is the most commonly used eukaryotic microorganism, although a number of other strains are commonly available. Strains of Saccharomyces cerevisiae having the identifying characteristics of strain AB107-30(4)-VN#2 (ATCC Accession No. 20937), particularly its resistance to 4M orthovanadate, is particularly suitable for DNase expression. With this VN#2 strain, it is desirable to stably transform the cells with a high-copy-number plasmid derived from a yeast 2-micron plasmid, *id.* Generally, the plasmid YRp7 is a satisfactory expression vector in yeast (Stinchcomb, *et al.*, "Nature" 282: 39 [1979]; Kingsman *et al.*, "Gene" 7: 141 [1979]; Tschemper *et al.*, "Gene" 10: 157 [1980]). This plasmid already contains the trp1 gene which provides a selection marker for a mutant strain of yeast lacking the ability to grow in tryptophan, for example ATCC no. 44076 or PEP4-1 (Jones, "Genetics" 85: 12 [1977]). The presence of the trp1 lesion as a characteristic of the yeast host cell genome then provides an effective environment for detecting transformation by growth in the absence of tryptophan. Expression in pichia (U.S. 4,808,537) is also satisfactory.

Suitable promoting sequences for use with yeast hosts include the promoters for 3-phosphoglycerate kinase (Hitzeman *et al.*, "J. Biol. Chem." 255: 2073 [1980]) or other glycolytic enzymes (Hess *et al.*, "J. Adv. Enzyme Reg." 7: 149 [1968]; and Holland, "Biochemistry" 17: 4900 [1978]), such as enolase, glyceraldehyde-3-phosphate dehydrogenase, hexokinase, pyruvate decarboxylase, phosphofructokinase, glucose-6-phosphate isomerase, 3-phosphoglycerate mutase, pyruvate kinase, triosephosphate isomerase, phosphoglucose isomerase, and glucokinase.

Other yeast promoters, which are inducible promoters having the additional advantage of transcription controlled by growth conditions, are the promoter regions for

alcohol dehydrogenase 2, isocytochrome C, acid phosphatase, degradative enzymes associated with nitrogen metabolism, metallothionein, glyceraldehyde-3-phosphate dehydrogenase, and enzymes responsible for maltose and galactose utilization. Suitable vectors and promoters for use in yeast expression are further described in R. Hitzeman *et al.*, European Patent Publication No. 73,657A.

Expression control sequences are known for eukaryotes. Virtually all eukaryotic genes have an AT-rich region located approximately 25 to 30 bases upstream from the site where transcription is initiated. Another sequence found 70 to 80 bases upstream from the start of transcription of many genes is a CXCAAT region where X may be any nucleotide. At the 3' end of most eukaryotic genes is an AATAAA sequence which may be the signal for addition of the poly A tail to the 3' end of the coding sequence. All of these sequences may be inserted into mammalian expression vectors.

Suitable promoters for controlling transcription from vectors in mammalian host cells are readily obtained from various sources, for example, the genomes of viruses such as polyoma virus, SV40, adenovirus, MMV (steroid inducible), retroviruses (e.g. the LTR of HIV), hepatitis-B virus and most preferably cytomegalovirus, or from heterologous mammalian promoters, e.g. the beta actin promoter. The early and late promoters of SV40 are conveniently obtained as an SV40 restriction fragment which also contains the SV40 viral origin of replication. Fiers *et al.*, Nature, 273: 113 (1978). The immediate early promoter of the human cytomegalovirus is conveniently obtained as a HindIII E restriction fragment. Greenaway, P.J. *et al.*, Gene 18: 355-360 (1982).

Transcription of a DNA encoding DNase by higher eukaryotes is increased by inserting an enhancer sequence into the vector. Enhancers are cis-acting elements of DNA, usually about from 10-300bp, that act on a promoter to increase its transcription. Enhancers are relatively orientation and position independent having been found 5' (Laimins, L. *et al.*, PNAS 78: 993 [1981]) and 3' (Lusky, M.L., *et al.*, Mol. Cell Bio. 3: 1108 [1983]) to the transcription unit, within an intron (Banerji, J.L. *et al.*, Cell 33: 729 [1983]) as well as within the coding sequence itself (Osborne, T.F., *et al.*, Mol. Cell Bio. 4: 1293 [1984]). Many enhancer sequences are now known from mammalian genes (globin, elastase, albumin, α -fetoprotein and insulin). Typically, however, one will use an enhancer from a eukaryotic cell virus. Examples include the SV40 enhancer on the late side of the replication origin (bp 100-270), the cytomegalovirus early promoter enhancer, the polyoma enhancer on the late side of the replication origin, and adenovirus enhancers.

Expression vectors used in eukaryotic host cells (yeast, fungi, insect, plant, animal, human or nucleated cells from other multicellular organisms) will also contain sequences necessary for the termination of transcription which may affect mRNA expression. These regions are transcribed as polyadenylated segments in the untranslated portion of the mRNA encoding DNase. The 3' untranslated regions also include transcription termination sites.

Expression vectors may contain a selection gene, also termed a selectable marker. Examples of suitable selectable markers for mammalian cells are dihydrofolate reductase (DHFR), thymidine kinase (TK) or neomycin. When such selectable markers are

successfully transferred into a mammalian host cell, the transformed mammalian host cell is able to survive if placed under selective pressure. There are two widely used distinct categories of selective regimes. The first category is based on a cell's metabolism and the use of a mutant cell line which lacks the ability to grow independent of a supplemented media. Two examples are: CHO DHFR⁻ cells and mouse LTK⁻ cells. These cells lack the ability to grow without the addition of such nutrients as thymidine or hypoxanthine. Because these cells lack certain genes necessary for a complete nucleotide synthesis pathway, they cannot survive unless the missing nucleotides are provided in a supplemented media. An alternative to supplementing the media is to introduce an intact DHFR or TK gene into cells lacking the respective genes, thus altering their growth requirements. Individual cells which were not transformed with the DHFR or TK gene will not be capable of survival in non supplemented media.

The second category is dominant selection which refers to a selection scheme used in any cell type and does not require the use of a mutant cell line. These schemes typically use a drug to arrest growth of a host cell. Those cells which are successfully transformed with a heterologous gene express a protein conferring drug resistance and thus survive the selection regimen. Examples of such dominant selection use the drugs neomycin (Southern *et al.*, J. Molec. Appl. Genet. 1: 327 (1982)), mycophenolic acid (Mulligan *et al.*, Science 209: 1422 (1980)) or hygromycin (Sugden *et al.*, Mol. Cell. Biol. 5: 410-413 (1985)). The three examples given above employ bacterial genes under eukaryotic control to convey resistance to the appropriate drug G418 or neomycin (geneticin), xgpt (mycophenolic acid) or hygromycin, respectively.

Suitable eukaryotic host cells for expressing human DNase include monkey kidney CV1 line transformed by SV40 (COS-7, ATCC CRL 1651); human embryonic kidney line (293 or 293 cells subcloned for growth in suspension culture, Graham, F.L. *et al.*, J. Gen Virol. 36: 59 [1977]); baby hamster kidney cells (BHK, ATCC CCL 10); chinese hamster ovary-cells-DHFR (CHO, Urlaub and Chasin, PNAS (USA) 77: 4216, [1980]); mouse sertoli cells (TM4, Mather, J.P., Biol. Reprod. 23: 243-251 [1980]); monkey kidney cells (CV1 ATCC CCL 70); african green monkey kidney cells (VERO-76, ATCC CRL-1587); human cervical carcinoma cells (HELA, ATCC CCL 2); canine kidney cells (MDCK, ATCC CCL 34); buffalo rat liver cells (BRL 3A, ATCC CRL 1442); human lung cells (W138, ATCC CCL 75); human liver cells (Hep G2, HB 8065); mouse mammary tumor (MMT 060562, ATCC CCL51); and, TRI cells (Mather, J.P. *et al.*, Annals N.Y. Acad. Sci. 383: 44-68 [1982]).

Construction of suitable vectors containing the desired coding and control sequences employ standard ligation techniques. Isolated plasmids or DNA fragments are cleaved, tailored, and religated in the form desired to form the plasmids required.

For analysis to confirm correct sequences in plasmids constructed, the ligation mixtures are used to transform *E. coli* K12 strain 294 (ATCC 31446) and successful transformants selected by ampicillin or tetracycline resistance where appropriate. Plasmids from the transformants are prepared, analyzed by restriction and/or sequenced by the

method of Messing *et al.*, Nucleic Acids Res. 9: 309 (1981) or by the method of Maxam *et al.*, Methods in Enzymology 65: 499 (1980).

Host cells are transformed with the expression vectors of this invention and cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants or amplifying the DNase gene. The culture conditions, such as temperature, pH and the like, are those previously used with the host cell selected for expression, and will be apparent to the ordinarily skilled artisan.

"Transformation" means introducing DNA into an organism so that the DNA is replicable, either as an extrachromosomal element or by chromosomal integration. Unless indicated otherwise, the method used herein for transformation of the host cells is the method of Graham, F. and van der Eb, A., Virology 52: 456-457 (1973). However, other methods for introducing DNA into cells such as by nuclear injection or by protoplast fusion may also be used. If prokaryotic cells or cells which contain substantial cell wall constructions are used, the preferred method of transfection is calcium treatment using calcium chloride as described by Cohen, F.N. *et al.*, Proc. Natl. Acad. Sci. (USA), 69: 2110 (1972).

"Transfection" refers to the introduction of DNA into a host cell whether or not any coding sequences are ultimately expressed. Numerous methods of transfection are known to the ordinarily skilled artisan, for example, CaPO_4 and electroporation. Transformation of the host cell is the indicia of successful transfection.

DNase is recovered and purified from recombinant cell cultures by methods used heretofore with human, bovine, ovine, or porcine DNase, including ammonium sulfate or ethanol precipitation, acid extraction, anion or cation exchange chromatography, phosphocellulose chromatography, hydrophobic interaction chromatography, affinity chromatography (e.g. using DNA or nucleotides on a solid support), hydroxyapatite chromatography and lectin chromatography. Moreover, reverse-phase HPLC and chromatography using anti-DNase antibodies are useful for the purification of DNase. As noted previously, (Price *et al.*, J. Biol. Chem. 244:917 [1969]) it is preferred to have low concentrations (approximately 0.1-5 mM) of calcium ion present during purification. Other divalent cations which stabilize DNase are also utilized. DNase may be purified in the presence of a protease inhibitor such as PMSF.

Human DNase is placed into therapeutic formulations together with required cofactors, and optionally is administered in the same fashion as has been the case for animal DNase such as bovine pancreatic DNase. The formulation of DNase may be liquid, and is preferably an isotonic salt solution such as 150 mM sodium chloride, containing 1.0 mM calcium at pH 7. The concentration of sodium chloride may range from 75- 250 mM. The concentration of calcium may range from 0.01 - 5 mM, and other divalent cations which stabilize DNase may be included or substituted for calcium. The pH may range from 5.5 - 9.0, and buffers compatible with the included divalent cation may also be utilized. The formulation may be lyophilized powder, also containing calcium.

Commercially available nebulizers for liquid formulations, including jet nebulizers and ultrasonic nebulizers are useful for administration. Liquid formulations may be directly nebulized and lyophilized power nebulized after reconstitution. Alternatively, DNase may be aerosolized using a fluorocarbon formulation and a metered dose inhaler, or inhaled as a lyophilized and milled powder. In addition, the liquid formulation of DNase may be directly instilled in the nasotracheal or endotracheal tubes in intubated patients.

The purified DNase is employed for enzymatic alteration of the visco-elasticity or the stickiness of mucous. Human DNase is particularly useful for the treatment of patients with pulmonary disease who have abnormal, viscous or inspissated purulent secretions in conditions such as acute or chronic bronchopulmonary disease (infectious pneumonia, bronchitis or tracheobronchitis, bronchiectasis, cystic fibrosis, asthma, TB or fungal infections), atelectasis due to tracheal or bronchial impaction, and complications of tracheostomy. For such therapies a solution or finely divided dry preparation of human DNase is instilled in conventional fashion into the bronchi, e.g. by aerosolization of a solution of DNase. Human DNase is also useful for adjunctive treatment for improved management of abscesses or severe closed-space infections in conditions such as empyema, meningitis, abscess, peritonitis, sinusitis, otitis, periodontitis, pericarditis, pancreatitis, cholelithiasis, endocarditis and septic arthritis, as well as in topical treatments in a variety of inflammatory and infected lesions such as infected lesions of the skin and/or mucosal membranes, surgical wounds, ulcerative lesions and burns. Human DNase finds utility in maintaining the flow in medical conduits communicating with a body cavity, including surgical drainage tubes, urinary catheters, peritoneal dialysis ports, and intratracheal oxygen catheters. DNase may improve the efficacy of antibiotics in infections (e.g., gentamicin activity is markedly reduced by reversible binding to intact DNA). It also may be useful as an oral supplement in cases of pancreatic insufficiency. DNase will be useful in degrading DNA contaminants in pharmaceutical preparations: the preparation is contacted with DNase under conditions for degrading the contaminant DNA to oligonucleotide and thereafter removing the oligonucleotide and DNase from the preparation. Use of DNase immobilized on a water insoluble support is convenient in this utility. Finally, DNase may be useful in treating non-infected conditions in which there is an accumulation of cellular debris, including cellular DNA. For example, DNase would be useful after systemic administration in the treatment of pyelonephritis and tubulo-interstitial kidney disease (e.g., with blocked tubules secondary to cellular debris), including drug-induced nephropathy or acute tubular necrosis.

DNase may also be administered along with other pharmacologic agents used to treat the conditions listed above, such as antibiotics, bronchodilators, anti-inflammatory agents, and mucolytics (e.g. n-acetyl-cysteine). It may also be useful to administer DNase along with other therapeutic human proteins such as growth hormone, protease inhibitors, gamma-interferon, enkephalinase, lung surfactant, and colony stimulating factors.

In order to facilitate understanding of the following examples certain frequently occurring methods and/or terms will be described.

"Plasmids" are designated by a lower case p preceded and/or followed by capital letters and/or numbers. The starting plasmids herein are either commercially available, publicly available on an unrestricted basis, or can be constructed from available plasmids in accord with published procedures. In addition, equivalent plasmids to those described are known in the art and will be apparent to the ordinarily skilled artisan.

"Digestion" of DNA refers to catalytic cleavage of the DNA with a restriction enzyme that acts only at certain sequences in the DNA. The various restriction enzymes used herein are commercially available and their reaction conditions, cofactors and other requirements were used as would be known to the ordinarily skilled artisan. For analytical purposes, typically 1 μ g of plasmid or DNA fragment is used with about 2 units of enzyme in about 20 μ l of buffer solution. For the purpose of isolating DNA fragments for plasmid construction, typically 5 to 50 μ g of DNA are digested with 20 to 250 units of enzyme in a larger volume. Appropriate buffers and substrate amounts for particular restriction enzymes are specified by the manufacturer. Incubation times of about 1 hour at 37°C are ordinarily used, but may vary in accordance with the supplier's instructions. After digestion the reaction is electrophoresed directly on a polyacrylamide gel to isolate the desired fragment.

Size separation of the cleaved fragments is performed using 8 percent polyacrylamide gel described by Goeddel, D. *et al.*, *Nucleic Acids Res.*, 8: 4057 (1980).

"Dephosphorylation" refers to the removal of the terminal 5' phosphates by treatment with bacterial alkaline phosphatase (BAP). This procedure prevents the two restriction cleaved ends of a DNA fragment from "circularizing" or forming a closed loop that would impede insertion of another DNA fragment at the restriction site. Procedures and reagents for dephosphorylation are conventional. Maniatis, T. *et al.*, Molecular Cloning pp. 133-134 (1982). Reactions using BAP are carried out in 50mM Tris at 68°C to suppress the activity of any exonucleases which may be present in the enzyme preparations. Reactions were run for 1 hour. Following the reaction the DNA fragment is gel purified.

"Oligonucleotides" refers to either a single stranded polydeoxynucleotide or two complementary polydeoxynucleotide strands which may be chemically synthesized. Such synthetic oligonucleotides have no 5' phosphate and thus will not ligate to another oligonucleotide without adding a phosphate with an ATP in the presence of a kinase. A synthetic oligonucleotide will ligate to a fragment that has not been dephosphorylated.

"Ligation" refers to the process of forming phosphodiester bonds between two double stranded nucleic acid fragments (Maniatis, T. *et al.*, *Id.*, p. 146). Unless otherwise provided, ligation may be accomplished using known buffers and conditions with 10 units of T4 DNA ligase ("ligase") per 0.5 μ g of approximately equimolar amounts of the DNA fragments to be ligated.

"Filling" or "blunting" refers to the procedures by which the single stranded end in the cohesive terminus of a restriction enzyme-cleaved nucleic acid is converted to a double strand. This eliminates the cohesive terminus and forms a blunt end. This process is a versatile tool for converting a restriction cut end that may be cohesive with the ends created

by only one or a few other restriction enzymes into a terminus compatible with any blunt-cutting restriction endonuclease or other filled cohesive terminus. Typically, blunting is accomplished by incubating 2-15 μ g of the target DNA in 10mM $MgCl_2$, 1mM dithiothreitol, 50mM NaCl, 10mM Tris (pH 7.5) buffer at about 37°C in the presence of 8 units of the Klenow fragment of DNA polymerase I and 250 μ M of each of the four deoxynucleoside triphosphates. The incubation generally is terminated after 30 min. phenol and chloroform extraction and ethanol precipitation.

Example 1

Cloning of Human Pancreatic DNase I

cDNA Library Preparation

A human pancreatic cDNA library was constructed in λ gt10 using polyadenylated mRNA prepared from freshly obtained and liquid N_2 frozen human pancreas (Lauffer *et al.*, Nature 318:334 [1985]). Using oligo dT primers and *EcoRI-SalI-XhoI-SstII* adapters, a cDNA library of 0.9×10^6 independent isolates of greater than 600 bp was obtained.

Oligonucleotide Probes

Two long probes were synthesized based on the amino acid sequence of bovine DNase I. Two segments of amino acid sequence which exhibited low redundancy were selected and mammalian codon usage tables were employed.

Probe 1: 5'GTG-CTG-GAC-ACC-TAC-CAG-TAT-GAT-GAT-GGC-TGT-GAG-TCC-TGT-GGC-AAT-GAC 3' (51 mer corresponding to the amino sequence Val-Leu-Asp-Thr-Tyr-Gln-Tyr-Asp-Asp-Gly-Cys-Glu-Ser-Cys-Gly-Asn-Asp)

Probe 2: 5'TAT-GAC-GTC-TAC-CTG-GAC-GTG-CAG-CAG-AAG-TGG-CAT-CTG-AAT-GAT-GTG-ATG-CTG-ATG-GGC-GAC-TTC-AAC-GC 3' (71 mer corresponding to the amino acid sequence Tyr-Asp-Val-Tyr-Leu-Asp-Val-Gln-Gln-Lys-Trp-His-Leu-Asn-Asp-Val-Met-Leu-Met-Gly-Asp-Phe-Asn)

Isolation of Human DNase I cDNA Clones

The two probes were end-labeled with T4 polynucleotide kinase and [^{32}P]adenosine triphosphate (Maniatis *et al.*, Molecular Cloning, [Cold Spring Harbor Laboratory, 1982]), and used separately to screen the human pancreatic cDNA library under low stringency hybridization conditions: 20% formamide, 5 x SSC (0.75 M NaCl, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5X Denhardt's solution, sonicated salmon sperm DNA (50 μ g/ml), 0.1% SDS, and 10% dextran sulfate at 42°C. Low stringency washes were carried out in 1X SSC and 0.1% SDS at 42°C. Three (1, 2, and 6) of 600,000 clones hybridized with both probes and contained 1.3 kB inserts. These were subcloned into M13 vectors (Messing *et al.*, Nucleic Acids Res. 9:309 [1981]) and sequenced by the chain-termination method (Sanger *et al.*, J. Mol. Biol. 143:161 [1980]).

Comparison of the deduced amino acid sequence of clone 6 with the amino acid sequence of bovine pancreatic DNase I revealed extensive homology. Notable, however, was a large deletion and a large insertion in the deduced amino acid sequence of clone 6. In addition the insertion contained a stop at its termination and had the characteristics of

a retained intron due to a misspliced message. Clones 1 and 2 also contained the putative intron.

Two additional exact nucleotide probes from the sequence of clone 6 were synthesized for obtaining additional clones.

5 Probe 4 (N-terminal probe): 5' CTG-AAG-ATC-GCA-GCC-TTC-AAC-ATC-CAG-ACA-TTT-GGG-GAG-ACC (42 mer)

Probe 5 (putative intron probe): 5'TCC-GCA-TGT-CCC-AGG-GCC-ACA-GGC-AGC-GTT-TCC-TGG-TAG-GAC (42 mer)

10 The probes were labeled with ^{32}P and used to rescreen 1.3×10^6 clones from the human pancreatic cDNA library at high stringency: 50% formamide, 5 x SSC (0.75 M NaCl, 0.075 M sodium citrate), 50 mM sodium phosphate (pH 6.8), 0.1% sodium pyrophosphate, 5X Denhardt's, sonicated salmon sperm DNA (50 $\mu\text{g}/\text{ml}$), 0.1% SDS, and 10% dextran sulfate at 42°C. Washes were carried out at 42°C in 0.2X SSC and 0.1% SDS. Four clones hybridized with probe 4 (N-terminal probe) and not with probe 5 (putative intron probe).
15 Of these, clone 18-1, which contained an insert of approximately 1.1 kB by PAGE, was subcloned into M13 and sequenced. The full nucleotide sequence of clone 18-1 and the deduced amino acid sequence is shown in Figure 1.

Clone 18-1 is composed of 1039 bp and has a long open reading frame without the intron found in clone 6. As noted, two possible initiation codons (ATG) are present
20 (positions 160-162 and 169-171). Either may be used. The former ATG with a purine at position -3 more closely conforms to the Kozak rule (Kozak, Cell 44:283 [1986]). Between the putative initiation codons and the nucleotides corresponding to the N-terminal leucine (CTG at position 226-228 are nucleotides encoding a short, relatively hydrophobic amino acid sequence (19-22 amino acids in length) which is a likely secretion signal sequence.

25 Comparison of the deduced amino acid sequence of human DNase I with bovine DNase I reveals extensive amino acid homology (Figure 2). The human and bovine proteins are 260 aa in length and possess an N-terminal leucine. The major structural features of the bovine protein, which include the four cysteines (101, 104, 173 and 209), the two potential N-linked glycosylation sites (18 and 106), and the active site histidine (134), are
30 conserved. Overall there is approximately 77% amino acid identity.

The six regions of greatest amino acid diversity (amino acid residues 27-39, 83-96, 115-126, 156-161, 219-234 and 243-247) each contain more than three differences and more than 54% of the amino acids are variable. Interestingly, these regions are also variable
35 when the bovine sequence is compared with the ovine and porcine. Some of these regions are exposed loop structures according to the Xray crystal structure of bovine DNase (Oefner *et al.*, J. Mol. Biol. 192:605 [1986]), and thus would be predicted to be relatively immunogenic. Thus, it is likely that the amino acid differences between the human and the bovine sequences may lead to immunologic reactions.

Example 2

Assays for DNase Activity

In addition to standard ELISA (see example 4) and RIA, three assays have been developed to detect DNase activity.

- 5 1. Hydrolysis of ^{32}P -labeled DNA. Radiolabeled ^{32}P -DNA was prepared using an M13 single-stranded template, a 17mer sequencing primer, ^{32}P -dCTP, non-radioactive dATP, dTTP, and dGTP, and Klenow. Briefly, 1.5 λ MgCl₂ (35 mM), 1.5 λ 10x restriction buffer (70 mM Tris-HCl, pH 7.6; 35 mM dithiothreitol; 1 mM EDTA), and 6 λ H₂O were mixed with 1 λ template (approximately 1 μg) and 1.5 λ Palmer (0.5 μM) and heated to 55°C for 7 min. Nucleotide mix was prepared by taking 40 λ ^{32}P -dCTP (sp. act. 3000 Ci/mmol; 400 μCi) plus 1 λ each of 2 mM stocks of non-radioactive dATP, dTTP, and dGTP to dryness and then reconstituting the nucleotides in 7 λ 1X restriction buffer. The nucleotide mix and 1 λ Klenow were added to the template-primer mixture and the reaction was incubated at 37°C. After 15 min, 2 λ of a non-radioactive deoxynucleotides were added and the incubation was continued for an additional 15 min. Radiolabeled DNA was then separated from free nucleotides by centrifugation through Sephadex G-50 (Maniatis *et al.*, [1982]).

20 DNase activity is measured by incubating samples with 100,000 cpm ^{32}P -DNA plus 80 $\mu\text{g}/\text{ml}$ non-radioactive salmon sperm DNA in DNase buffer (10 mM Tris-HCl pH 7, 4 mM MgCl₂, 4 mM CaCl₂) for 45 min at 37°C. The reaction is terminated by the addition of one-half volume of non-radioactive DNA (2 mg/ml) and one volume of ice-cold 20% trichloroacetic acid. After 10 min at 4°C, the mixture is centrifuged at 12,000g X 10 min, and an aliquot of the supernatant is counted. The presence of acid-soluble counts in the supernatant reflects DNase activity. Each day a standard curve is generated by testing 0.1 - 200 ng of bovine DNase I (Sigma D-5025).

- 25 2. Agar plate DNase assay. Smith, Hancock, and Rhoden (Applied Microbiology, 18:991 [1969]) described a test agar containing methyl green and DNA for determining DNase activity of microorganisms. This assay was modified in order to develop a rapid semi-quantitative assay for soluble DNase activity in order to screen cell supernatants to monitor expression and to screen column fractions to monitor purification. To prepare the agar, bacto agar (7.5 g) is melted in 500 ml of buffer (25 mM Tris pH 7.5, 5 mM MgCl₂, 5 mM CaCl₂, 0.1% sodium azide). Salmon sperm DNA (1.0 g) and methyl green (17.5 mg) are added. After stirring for 1-2 hr at 55°C, and autoclaving, plates are poured and stored at 4°C. DNase activity is measured by spotting 0.5-5 λ aliquots onto the plates, which are then incubated at room temperature or 37°C for 4-48 hr. A standard curve is generated by aliquoting 0.1-1000 ng of bovine DNase I. DNase is readily measured by the size of the clear zones in the agar, there being a logarithmic relationship between DNase concentration and diameter of the clear zones. This assay format also is applicable for the rapid identification of high-expressing DNase-producing clones, either with a view towards

producing DNase or towards screening transformants in which the DNase is used as a selectable marker or as a reporter gene.

In addition to using methyl green and DNA in an agar plate format, these reagents are also used in an aqueous format (e.g. in 96-well plates) to rapidly, sensitively, and specifically quantitate DNase activity.

3. SDS-polyacrylamide gel electrophoresis and xymography. SDS-polyacrylamide gel electrophoresis and xymography was performed by a modification of the procedure of Rosenthal and Lacks (Anal. Biochem. 80:76 [1977]). Briefly, the buffer system of Laemmli was used to prepare 12% polyacrylamide gels. Salmon sperm DNA (10 μ g/ml) and EDTA (2 mM) were added to both the stacking and the resolving gels prior to polymerization. Proteins were suspended in sample buffer, heated at 100°C for 3 min, prior to application to the gels. Electrophoresis was conducted at room temperature at constant current. Following electrophoresis, the gel was rinsed with water and incubated in 250 ml of 40 mM Tris-HCl, pH 7.5, 2 mM $MgCl_2$, 0.02% azide. After 1 hr, fresh buffer was added and the gel was soaked for 12 hr at 24°C. To reveal DNase activity, the gel was put into fresh buffer containing 2 mM $CaCl_2$ and 1 μ g/ml ethidium bromide, and then examined under short-wave UV light at intervals from 5 min to 24 hr. To stop the reaction EDTA is added (final concentration 15 mM), and the xymogram is photographed. The gel can then be stained for protein by Coomassie blue.

Example 3

Expression of Human DNase I

1. pRK.DNase.7

Plasmid pRK.DNase.7 was constructed from clone 18-1, described above, as follows:

The plasmid pRK5 was digested with *EcoRI*, dephosphorylated, and fragment 1 comprising the bulk of the plasmid was isolated. pRK5 is described in Suva *et al.*, *Science* 237:896 (1987); and EP Publ. 307,247, published 15 March 1989, where the pCIS2.8c28D starting plasmid is described in EP 278,776 published Aug. 17, 1988. The λ DNase clone 18-1 was digested with *EcoRI* and the insert (fragment 2) was isolated. Fragment 1 and fragment 2 were ligated and the ligation mixture transformed into *E. coli* strain 294. The transformed culture was plated on ampicillin media plates and resistant colonies selected. Plasmid DNA was prepared from transformants and checked by restriction analysis for the presence of the correct fragment.

pRK.DNase.7 was transfected into human embryonic kidney-293 cells for transient and stable expression. For transient expression of human DNase I, 60 mm plates of confluent HEK-293 cells (50%) were transfected as previously described (Eaton *et al.* 1986) by the calcium phosphate method (Wigler *et al.*, 1979). For stable expression of human DNase I, HEK-293 cells were similarly transfected simultaneously with pRK.DNase.7 and a plasmid expressing the neomycin resistance gene pRSV neo (Gorman *et al.*, 1985). Two days after transfection, the cells were passaged into standard medium (1:1 F12/DME

supplemented with L-glutamine, penicillin-streptomycin and 10% FBS) with 0.5 mg/ml G418 (Gentamicin sulfate; Gibco) for selection of stable lines.

Analysis was undertaken of supernatants of 293 cells transfected either transiently or stably with the DNase plasmid revealed 0.2 - 1.0 $\mu\text{g/ml}$ of DNase activity, as measured either by the ^{32}P -DNA hydrolysis assay or the green agar plate DNase assay. Analysis of the transfected cell supernatants by SDS-PAGE and xymography revealed a new protein band at approximately 35-37 kD with DNase activity. Additional studies showed the recombinant human DNase I produced in 293 cells required calcium for activity, was inhibited by EDTA, heat, and actin, and had greater activity for double stranded DNA than for single stranded DNA. The specific activity of human DNase expressed in 293 cells appeared comparable to that of bovine DNase.

2. pSVeDNaseDHFR3

pSVeDNaseDHFR3, a plasmid suitable for recombinant synthesis of human DNase I in CHO cells was constructed as follows:

An intermediate plasmid was constructed in order to remove a redundant polylinker region. Plasmid pRK.DNase.7 was digested with *EcoRI* and *SphI* and the largest fragment containing the 5' portion of the DNase coding region was isolated (fragment 3). Plasmid pRK.DNase.7 was digested with *SalI*, blunted with Klenow, digested with *SphI*, and the intermediate size fragment containing the 3' portion of the DNase coding region was isolated (fragment 4). pRK5 was cut with *SmaI* and *EcoRI* and the fragment comprising the bulk of the plasmid was isolated (fragment 5). Fragments 3, 4 and 5 were ligated and the mixture was transformed into *E. coli* strain 294. The transformed culture was plated on ampicillin media plates and resistant colonies selected. Plasmid DNA was prepared from transformants and checked by restriction analysis for the presence of the correct fragment. The resulting plasmid is referred to as pRKDNaseInt.

Plasmid pE342HBV.E400D22 (Crowley *et al.*, "Mol. Cell Biol." 3:44 [1983]) was digested with *EcoRI* and *PvuI* and the smallest fragment containing the SV40 early promoter and part of the β -lactamase gene was isolated (fragment 5). Plasmid pE342HBV.E400D22 was also digested with *BamHI* and *PvuI* and the fragment comprising the bulk of the plasmid containing the balance of the β -lactamase gene as well as the SV40 early promoter and the DHFR gene was isolated (fragment 6). Plasmid pRKDNaseInt was digested with *EcoRI* and *BamHI* and the DNase coding fragment was isolated (fragment 7). Fragments 5, 6, and 7 were ligated and the mixture was transformed into *E. coli* strain 294. The transformed culture was plated on ampicillin media plates and resistant colonies selected. Plasmid DNA was prepared from transformants and checked by restriction analysis for the presence of the correct fragment. The resulting plasmid is referred to as pSVeDNaseDHFR3.

For stable expression of human DNase I, using the above plasmid, 60 mm plates of confluent CHO cells (DP-7) were transfected by the calcium phosphate method and grown initially in selective medium. Unamplified cell lines have grown out whose medium contains approximately 0.02-0.1 $\mu\text{g/ml}$ of DNase activity, as measured either by the ^{32}P -

DNA hydrolysis assay or the green agar plate DNase assay. It is anticipated that higher levels (at least 5X) of expression would be achieved if these cells were grown to high density in a fermentor. Individual clones would be selected for their individual levels of DNase expression to pick high secreting cells, and thereafter amplifying each selected clone in the presence of increasing concentrations of MTX (12.5 to 2000 nM)

3. pDNA11

A plasmid was constructed suitable for recombinant synthesis of DNase in *E. coli* as a secreted protein. This plasmid is called pDNA11 and was constructed as follows.

Plasmid pTF.III (EP Publ. No. 278,776) was digested with NsiI and SalI and the largest fragment comprising the bulk of the plasmid was isolated (fragment 8). Plasmid pRKDNase7 was digested with SalI and BstXI and the 798 bp fragment comprising most of the coding region was isolated (fragment 9). Two synthetic oligonucleotides were synthesized:

DLink 1: 5'TTG-AAG-ATC-GCA-GCC-TTC-AAC-ATC-CAG-ACA-T (31mer)

DLink 3: 5'CTG-GAT-GTT-GAA-GGV-TGC-GAT-CTT-CAA-TGC-A (31mer)

Fragments 8 and 9 and synthetic oligonucleotides DLink 1 and DLink 3 were ligated and the mixture was transformed into *E. coli* strain 294. The transformed culture was plated on ampicillin media plates and resistant colonies selected. Plasmid DNA was prepared from transformants and checked by restriction analysis for the presence of the correct fragment and preservation of the NsiI and BstXI restriction sites. Several plasmids were sequenced to confirm incorporation of correct synthetic DNA. 294 cells transformed with pDNA11 expressed >500 mg/L of two new major proteins as revealed by SDS-PAGE--a major band at approximately 32 kD and a minor band at approximately 30 kD. Amino acid sequence analysis of the two bands revealed N-terminal sequences of Met-Lys-Lys-Asn-Ile-Ala and Leu-Lys-Ile-Ala-Ala-Phe, respectively. Thus, the higher MW band represents unprocessed human DNase and the lower MW band represents properly processed native human DNase.

Human DNase expressed in *E. coli* is active. 294 cells transformed with pDNA11 grown on agar plates supplemented with calcium, magnesium, and low phosphate revealed secretion of active DNase, as evidenced the presence of a clear zone surrounding the transformed cells, and not control cells. In addition, transformed cells solubilized with SDS and beta-mercaptoethanol were run into SDS-PAGE gels and xymography was performed. DNase activity was associated with the band of properly processed human DNase, but not with unprocessed human DNase.

4. pDNA2

A plasmid was constructed for recombinant expression of human DNase I as an intracellular protein in *E. coli*. The plasmid is called pDNA2, and was constructed as follows.

Plasmid pHGH207/307 was prepared from pHGH207 (U.S. Patent 4,663,283) by removing the *EcoRI* site upstream from the trp promoter (*EcoRI* digested, blunted and religated).

Plasmid pHGH207/307 was digested with XbaI and SalI and the largest fragment comprising the bulk of the plasmid was isolated (fragment 10). Plasmid pRK.DNase.7 was digested with SalI and BstXI and the 798 bp fragment comprising most of the coding region was isolated (fragment 9). Two synthetic oligonucleotides were synthesized:

5 DLink 4: 5'CTAGAATTATG-TTA-AAA-ATT-GCA-GCA-TTT-AAT-ATT-CAA-ACA-T (42mer)

DLink5:5'TTG-AAT-ATT-AAA-TGC-TGC-AAT-TTT-TAACATAATT(34mer)

Fragments 9 and 10 and synthetic oligonucleotides DLink 4 and DLink 5 were ligated and the mixture was transformed into *E. coli* strain 294. The transformed culture was
10 plated on ampicillin media plates and resistant colonies selected. Plasmid DNA was prepared from transformants and checked by restriction analysis for the presence of the correct fragment and preservation of the XbaI and BstXI restriction sites. Several plasmids were sequenced to confirm incorporation of correct synthetic DNA.

294 cells transformed with pDNA2 expressed one new major protein as revealed by
15 SDS-PAGE of approximately 30kD. Amino acid sequence analysis of protein revealed N-terminal sequence Met-Leu-Lys-Ile-Ala-Ala-Phe, corresponding to human Met-DNase.

Human Met-DNase expressed directly in *E. coli* is also active. Transformed cells solubilized with SDS and beta-mercaptoethanol were run into SDS-PAGE gels and xymography was performed. DNase activity was associated with the band of human Met-
20 DNase.

EXAMPLE 4

Further Analysis of DNase Expression

a. DNase Expression Vectors

The human pancreatic deoxyribonuclease (DNase) I cDNA from plasmid
25 pRK.DNase.7 described above, which contains the entire insert from DNase cDNA clone 18-1 isolated from a λ gt10 human pancreatic cDNA library in vector pRK5, was transferred into pRK5 to create the intermediate expression vector pRK.DNase.3. In this plasmid (pRK.DNase.3), DNase synthesis is directed by the CMV transcription regulatory elements. A splice unit, described below, is located between the transcription and translation initiation
30 sites. For generation of DNase expression vectors, the CMV transcription regulatory sequences and the splice unit of pRK.DNase.3 were replaced by the SV40 transcription regulatory sequences and different splice donor-intron-splice acceptor units as described below. For comparison, a corresponding vector lacking the splice unit was also created (pSve.DNase).

35 1. pRK.DNase.3

Vector pRK.DNase.3 (Fig. 3) was constructed as follows: pRK5 was digested with SmaI and SalI, which cut exclusively in the polylinker region between the 5' and 3' control sequences, and the large fragment was isolated. The pRK5 vector contains a splice donor-intron-splice acceptor region upstream of a coding region and downstream of a promoter,
40 where the intron region consists of a cytomegalovirus (CMV) immediate early splice donor and intron sequences, a bacteriophage SP6 promoter insert, and immunoglobulin (Ig) heavy

chain variable region (V_H) intron and splice acceptor sequences. Vector pRK.DNase.7 was cleaved with BsmI, the 3' protruding ends were trimmed back with T4 DNA polymerase, and the material was redigested with SalI to release the entire human DNase I coding sequence as a 921-nt fragment. After gel isolation, this fragment was ligated to the pRK5 large fragment using standard ligation methodology (Maniatis *et al.*, 1982, *supra*) to create vector pRK.DNase.3.

pRK.DNase.3 contains CMV transcription regulatory elements, and a splice unit located between the transcription and translation initiation sites ("Intron" in Fig. 3). In this vector, the splice unit of the pRK5 vector is present without any modifications.

2. pSve.DNase

Vector pSve.DNase was constructed as follows (Fig. 3): The regulatory sequences preceding the DNase coding region in vector pRK.DNase.3 were separated from the remainder of the vector by digestion with SstI and ClaI; DNA prepared from dam^+ bacterial host cells was used to prevent cleavage of the second ClaI site in the vector, located towards the 3' end of the SV40 early polyadenylation region. The largest fragment lacking the 5' control region was gel isolated.

DHFR expression vector pE348DHFRUC served as a source of the SV40 transcription regulatory sequences. The vector pE348DHFRUC (Vannice and Levinson, *J. Virology*, 62:1305-1313, 1988, where it is designated pE, Figure 1) contains the SV40 enhancer and early promoter region upstream of the HindIII site, including the SV40 early sites of transcription initiation (position 5171 in the virus), preceding cDNA encoding murine dihydrofolate reductase (DHFR), which is followed by the 584-bp Hepatitis B virus (HBV) polyA signal in plasmid pML1 from the GamHI to the BGIII sites of HBV. This plasmid contains a polylinker immediately upstream of the SV40 sequences. The SV40 transcription regulatory sequences, were released by digestion with SstI and ClaI, and the resulting 5' protruding ends were filled in using Klenow polI in the presence of all four deoxyribonucleotides (dNTPs: dATP, dGTP, dCTP, TTP). Upon subsequent digestion with XbaI, the SV40 transcription regulatory sequences (enhancer and early promoter, including the SV40 early sites of transcription initiation), present on the smaller XbaI-ClaI fragment (360 nucleotides) were gel isolated.

The smaller fragment from pE348DHFRUC described immediately above was gel isolated and ligated to the large pRK.DNase.3 fragment to generate vector pSve.DNase. In this vector, DNase synthesis is directed by the SV40 transcription control sequences, but no splice unit is present between these and the DNase coding region.

3. pSVI.DNase

Vector pSVI.DNase (Fig. 4) was prepared after insertion of the DNase coding sequence into an intermediate plasmid, pRK5.SVe. This intermediate was created by replacing the pRK5 CMV transcription regulatory elements, located between SpeI and SacII restriction sites, with the small XbaI-HindIII fragment from pE348DHFRUC that contains the SV40 early promoter and enhancer. The 3' protruding ends generated by SacII digestion of pRK5 were chewed back with T4 DNA polymerase, and the 5' protruding ends resulting

from HindIII digestion of pE348DHFRUC were filled in using T4 polymerase in the presence of all four dNTPs.

For construction of pSVI.DNase, the DNase coding sequence was isolated from vector pRK.DNase.3 by cleavage with EcoRI and HindIII, and inserted into the large fragment of pRK5.Sve that had been isolated after digestion with the same two enzymes. Vector pSVI.DNase contains the SV40 transcription regulatory elements (enhancer and early promoter, including the SV40 early sites of transcription initiation) and mRNA cap sites, followed by the splice-donor-intron-splice acceptor unit of the pRK5 vector without any modifications, the cDNA encoding DNase, the SV40 early polyadenylation ("polyA") region, and the SV40 origin of replication ("ori") regions from SV40.

The complete nucleotide sequence of pSVI.DNase up to, but not including, the coding region of DNase is shown in Fig. 6.

4. pSVI2.DNase, pSVI3.DNase, pSVI5.DNase, and pSVI6B.DNase

Vectors pSVI2.DNase, pSVI3.DNase, pSVI5.DNase, and pSVI6B.DNase were constructed (Fig. 5) by recombining two fragments in each case. The first was the large pRK.DNase.3 fragment resulting from digestion with EcoRI, treatment with T4 DNA polymerase in the presence of dNTPs, and subsequent cleavage with SstI; the second was in each case the small fragment containing the SV40 5' regulatory sequences and a modified splice unit.

Modifications to splice units for enhancing recombinant expression in mammalian cells are known in the art. Fig. 11 shows a schematic representation of the splice unit nucleotide sequences involved in the preparation of the vectors of this example, i.e., SVI, SVI2, SVI3, SVI5, and SVI6B. The boxes represent changes from the SVI sequence, the double underlining is a spurious ATG codon, the underlining shows spurious splice sites and added or changed branchpoint sequence (BPS) regions, the breaks in sequence represent deletions of the nucleotides for SVI3-SVI5, the "..." designation indicates sequence not shown, and the carets indicate the 5' and 3' cleavage sites within the splice donor and splice acceptor, respectively, of the the splice unit. These sequences may be prepared by known methods of protein synthesis, or by standard modifications of the pSVI sequence.

Figs. 7-10 show the complete nucleotide sequences of pSVI2.DNase, pSVI3.DNase, pSVI5.DNase, and pSVI6B.DNase, respectively, up to but not including the coding region of DNase. The splice unit sequences of Fig. 11 are incorporated in Figs. 7-10.

b. Transient DNase Expression

Transient expression directed by the different DNase vectors was analyzed after transfection into CHO dhfr⁻ cells. Cells were transfected by a modification of the DEAE-dextran procedure and levels of DNase accumulated in the cell media 36 to 48 hours after transfection. Approximately 4×10^5 cells were plated per well in six-well 35 mm culture dishes. The following day, the volume of 2 μ g DNase expression vector was adjusted to 15 μ l by the addition of TBS (137 mM NaCl, 5 mM KCl, 1.4 mM Na₂PO₄, 24.7 mM TrisHCl, 1.35 mM CaCl₂, 1.05 mM MgCl₂, pH 7.5). 30 μ l DEAE-dextran (10/ mg/ml) and 2 ml serum-free culture medium containing 100 μ M chloroquine were then added.

The cell media was removed, the cells were rinsed once with PBS (phosphate buffered saline, pH 7.5), and the DNA mixture was added. This was followed two to three hours later by a glycerol shock, and the cells were covered with 2 ml regular growth media until assayed. The DNase vectors were cotransfected with 2 μ g of a control plasmid, pRSV.hGH, which directs expression of the human growth hormone (hGH) gene controlled by the transcription regulatory sequences in the long terminal repeat (LTR) of Rous sarcoma virus. This plasmid may be prepared by replacing the ras promoter of rasP.hGH described in Cohen and Levinson, *Nature*, 334: 119-124 (1988) with the RSV promoter. The amount of hGH synthesized in each case served as a standard to allow for a more precise comparison of the DNase levels obtained in the different transfections. Shown below are the levels of DNase and hGH produced in a typical experiment performed in duplicate:

Vector	ng/ml DNase		ng/ml hGH		(corrected) ng/ml DNase	
	run1	run2	run1	run2	run1	run2
pSVe.DNase	19.7	17.4	50.1	42.0	8.6	9.2
pSVI.DNase	17.9	13.8	29.7	20.4	12.8	14.7
pSVI2.DNase	34.2	30.5	41.9	40.3	18.0	17.0
pSVI3.DNase	37.8	28.7	45.2	40.5	18.0	15.1
pSVI5.DNase	28.4	22.1	37.2	28.7	16.7	17.0
pSVI6B.DNase	28.5	37.8	61.3	67.5	10.2	12.2

DNase levels in the media were measured by a standard ELISA using serum from rabbits injected either with human DNase or bovine DNase and adjuvant (*Practice and Theory of Enzyme Immunoassays*, P.Tijssen, Chapter 5, "Production of antibodies", pg. 43-78 (Elsevier, Amsterdam 1985)). hGH levels were determined using a commercially available assay kit (IRMA, immunoradiometric assay) purchased from Hybritech, Inc., La Jolla, CA.

The data in the last column suggest that DNase expression directed by vectors pSVI2.DNase, pSVI3.DNase, and pSVI5.DNase is somewhat higher than that obtained with the parental vector pSVI.DNase. The numbers in the first column show more significant differences that now apply also to pSVI6B.DNase. Although it would appear that the third column presents the more credible set of data, it is not certain that efficient hGH synthesis does not adversely affect the level of DNase synthesis. For example, without limitation to any one theory, expression at this level may likely cause competition for components in the secretory pathway, and as a result a reduced DNase level when hGH expression is high. Other competitive effects may also bias the results such that the first column of data may well represent the actual differences in expression capability among the various DNase vectors. In either case, it is clear that at least some of the vectors containing a modified splice unit express higher levels of DNase in a transient assay than the corresponding vector that has the original splice unit.

c. Stable DNase Expression

2 μ g of plasmid pSve.DNase, pSVI.DNase, pSVI2.DNase, pSVI3.DNase, pSVI5.DNase, or pSVI6B.DNase were transfected into CHO-dhfr⁻ cells in a 60-mm dish with 0.1 μ g of pFD11. After two days the cells were split 90% and 10% in 10-cm dishes. When colonies
 5 appeared, they were counted and assayed as mixed colonies. Per cell assays were performed in duplicate (designated A or B in the table below), except for pSVI2.DNase which was measured once. In this assay, the cell line was set up at 2×10^5 cells/well-6 well dish in 3 ml. Three days later cells were counted and the media was assayed for DNase using the DNase ELISA described above with a range of 0.2 to 25 ng/ml. The results are indicated
 10 below:

	<u>Vector</u>	<u>pg/cell/day DNase</u>	
		<u>A</u>	<u>B</u>
	pSve.DNase	0.057	0.040
	pSVI.DNase	0.079	0.016
15	pSVI2.DNase	0.067	
	pSVI3.DNase	0.048	0.043
	pSVI5.DNase	0.014	0.005
	pSVI6B.DNase	0.039	0.062

20

Example 5

Reduction in Viscosity of Purulent Sputum by Recombinant Human DNase

The effects of recombinant human DNase I and pure bovine DNase I (Worthington) on purulent sputum produced by a patient with cystic fibrosis was examined using a simple
 25 pourability assay. Briefly, samples were incubated with approximately 100 μ l of sputum in Eppendorf test tubes. After various periods of time at 37° C, the tubes were inverted and the ability of the sputum to pour down the side of a test tube was evaluated on a scale of 0 (no movement) to 5+ (free-flowing down the side of the tube). Whereas 293 supernatants from human DNase I transfected cells caused a change of 4-5+ after 30 min
 30 incubation, untransfected cell supernatants had no effect. The specificity was confirmed by showing that EDTA--which inhibits bovine and human DNase--completely prevented the 293 supernatants from human DNase I transfected cells from liquefying cystic fibrosis sputum. In addition, the effects on sputum of bovine DNase which was pure and free of proteases was examined for the first time. Previously published reports all utilized bovine
 35 DNase which acknowledged to be contaminated with significant quantities of chymotrypsin and trypsin, proteins which had been shown to have activity on sputum by themselves. Pure bovine DNase I, free of proteases, rapidly liquified purulent sputum. Thus, pure DNase alone is effective at reducing the viscosity of sputum.

Claims:

1. Human DNase unaccompanied by associated native glycosylation.
2. A DNA isolate encoding human DNase.
3. The isolate of claim 2 wherein the isolate is free of DNase introns.
- 5 4. The isolate of claim 2 wherein the isolate is free of genomic DNA which encodes another polypeptide from the source of the DNA.
5. The isolate of claim 2, wherein the DNA encodes a polypeptide having the amino sequence shown in figure 1.
6. A recombinant expression vector comprising DNA encoding human DNase.
- 10 7. A composition comprising a cell transformed with the recombinant expression vector of claim 6.
8. The composition of claim 7 wherein the cell is a mammalian cell.
9. A process for producing DNase which comprises transforming a host cell with nucleic acid encoding DNase, culturing the transformed cell and recovering DNase from
15 the culture.
10. The process according to claim 9 wherein the DNase is recovered from the culture medium of the host cell.
11. The process according to claim 10 wherein the host cell is a eukaryotic cell.
12. The process of claim 9 wherein the DNase is human DNase.
- 20 13. The process of claim 12 wherein the eukaryotic cell is a human embryonic kidney cell line.
14. The process of claim 12 wherein the nucleic acid encodes a human DNase preprotein.
15. The process of claim 14 wherein the preprotein is human preDNase.
- 25 16. The process of claim 12 wherein the human DNase is secreted into the culture medium.
17. The process of claim 12 wherein the human DNase is unglycosylated.
18. A pharmaceutical preparation useful for enzymatic treatment comprising a therapeutically effective amount of human DNase and a pharmaceutically acceptable carrier.
- 30 19. The preparation of claim 18 which is sterile.
20. The preparation of claim 18 wherein the DNase is entirely free of proteases.
21. The preparation of claim 20 in the form of an aerosol.
22. The preparation of claim 18 wherein the DNase has the sequence of the mature DNase depicted in Fig. 1.
- 35 23. A polynucleotide probe containing at least about 10 bases which is capable of hybridizing under stringent conditions to the human DNase gene.
24. A conjugate of human DNase and a nonproteinaceous polymer.
25. The conjugate of claim 24 wherein the polymer is surgical tubing selected from the group of catheters and drainage conduits.
- 40 26. The conjugate of claim 24 which is water soluble.

27. The conjugate of claim 24 wherein the polymer is a polyoxyalkylene or polyalkylene glycol.
28. A method for the treatment of a patient having an accumulation of purulent material comprising administering pure DNase free of proteases to the patient in an amount therapeutically effective to reduce the visco-elasticity of the material.
- 5 29. A method for enhancing the activity of antibiotics comprising administering to a patient a therapeutically effective amount of an antibiotic and a therapeutically effective amount of DNase.
30. A method for maintaining the flow of fluid in conduits communicating with a patient's body cavity comprising contacting the interior of the conduit with DNase.
- 10 31. The method of claim 30 wherein the DNase is covalently bound to the conduit.
32. The method of claim 30 wherein a solution of the DNase is passed through the conduit into the body cavity.
33. A method for purifying pharmaceutical preparations so as to be free of contaminant DNA comprising contacting the preparation with DNase under conditions for degrading the contaminant DNA to oligonucleotides and removing the oligonucleotides and DNase from the preparation.
- 15 34. The method of claim 33 wherein the DNase is immobilized on a water insoluble support.
- 20 35. A method for the treatment of a patient having cystic fibrosis comprising administering to such patient a therapeutically effective dose of pure DNase free of proteases.

Fig. 1.

1 TCCTGCACAG GCAGTGCCTT GAAGTGCCTT TTCCAGAGACC TTCTTCTTCAFA GACTACTTTT TTTTCTTTTAA GCAGCAAAAG GAGAAAAATTG TCATCAAAGG
 AGGACTGTGTC CGTCACGGAA CTTACACGAAG AAGTCTCTGG AAAGAAGTAT CTGATGAATAA AAAAGAAATT CGTCGTTTC CTCTTTTAC AGTAGTTTCC
 1 SerCysThrG lySerAlaLe uLysCysPhe PheArgAspL euSerSerAM *ThrThrPhe PheSerLeuS erSerLysAr gArgLysLeu SerSerLysAsp
 101 ATATTCCAGA TTCTTGACAG CATCTCTGTC ATCTCTGAGG ACATCACCAT CATCTCAGCA TGAGGGGGAT GAAGCTGCTG GGGCGCTGC TGGCACTGGC
 TATAGGTCT AAGAAGTCT GTAAGAGCAG TAGAGACTCC TGTAAGTGA TAAGAGTCT ACTCCCGTA CTTGACGAC CCCCGGACG ACCGTGACCG
 35 IleProAs pSerOP*Gln HisSerArgH isLeuOP*Gl yHisHisHis HisLeuArgM etArgGlyMe tLysLeuLeu GlyAlaLeuL euAlaLeuAla
 201 GGCCTACTG CAGGGGGCCG TGTCCTGAA GATCCAGCC TTCAACATCC AGACATTTGG GGAGACCAAG ATGTCCAATG CCACCTCTGT CAGCTACATT
 CCGGATGAC GTCCCCCGG ACAGGACTT CTAGGTCTGG AAGTTGTAG TCTGTAAACC CCTCTGTTTC TACAGGTTAC GCTGGGACCA GTCCATGTAA
 68 AlaLeuLeu GlnGlyAlaV alSerLeuLy sIleAlaAla PheAsnIleG lNThrPheGl yGluThrLys MetSerAsnA laThrLeuVa lSerTyriLe
 301 GTGCAGATCC TGAGCCGCTA TGACATCGCC CTGCTCCAGG AGGTCAGAGA CAGCCACCTG ACTGCGTGG GGAAGCTGCT GCACAACCTC AATCAGGATG
 CACGCTAGG ACTCGGCGAT ACTGTAGCGG GACCAAGTCC TCCAGTCTCT GTCGGTGGAC TGACGGCACC CCTTCGACGA CCTGTTGGAG TTAGTCTCTAC
 101 ValGlnIleL euSerArgTy rasPileAla LeuValGlnG luValArgas pSerHisLeu ThrAlaValG lyLysLeuLe uAspAsnLeu AsnGlnAspAla
 401 CACCAACAC CTATCACTAC GTGGTCAGTG AGCCACTGGG ACGGAACAGC TATAAGGAGC GCTACCTGTT CGTGTACAGG CCTGACCAGG TGCTGCGGT
 GTGGTCTGTG GATAGTGATG CACCACTCAC TCGGTGACCC TGCTTGTGCG ATATTCCTCG CGATGGACAA GCACATGTCC GGACTGGTCC ACAGACGCCA
 135 ProAspTh rTyriHistyr valValSerG luProLeuGl yArgAsnSer TyrLysGluA rgTyriLeuPh evalTyriArg ProAspGlnv alSerAlaVal
 501 GGACAGCTAC TACTACGATG ATGGCTGCGA GCCCTGCGGG AACGACACCT TCAACCGAGA GCCAGCATT GTCCCGGTT TCTCCCGGTT CACAGAGGTC
 CCTGTGATG ATGATGCTAC TACCGACGCT CGGACGCCCC TTGCTGTGGA AGTTGGCTCT CGGTCCGTAA CAGTCCAAGA AGAGGCCAA GTGTCTCCAG
 168 AspSerTy rTyriAspA spGlyCysGl uProCysGly AsnAspThrP heAsnArgGl uProAlaIle ValArgPheP heSerArgPh eThrGluVal
 601 AGGAGTTTG CCATTGTTCC CTGTCATGG GCGCCGGGG ACCGAGTAGC CGAGATCGAC GCTCTCTATG ACGTCTACCT CGATGTCCA GAGAATGGG
 TCCCTCAAC GGTAAACAAG GGACGTACGC CGGGGCCCC TGGCTCATCG GCTCTAGCTG CGAGAGATAC TGCAGATGA CTTACAGGTT CTCTTACCC
 201 ArgGluPhea laileValPr oLeuHisAla AlaProGlyA spArgValAl aGluileAsp AlaLeuTyra spValTyriLe uAspValGln GlulysTrpGly
 701 GCTTGGAGGA CGTCATGTTG ATGGCGGACT TCAATGCGGG CTGACGCTAT GTGAGACCTT CCCAGTGGTC ATCCATCCGC CTGTGGACAA GCCCACCTT
 CGAAGCTCTT GCAGTACAAC TACCCGCTGA AGTTACGCC GACGTCGATA CACTCTGGA GGTACACCAG TAGGTAGCG GACACCTGTT CGGGTGGAA
 235 LeuGluAs pValMetLeu NetGlyAspP heAsnAlaGl yCysSertyr ValArgProS erGlnTrpSe rSerIleArg LeuTrpThrS erProThrPhe
 801 CCAGTGGCTG ATCCCGGACA GCGGTGACAC CACAGCTACA CCCACGCACT GTGCCATATGA CAGGATCGTG GTTGCGGGA TGCTGCTCCG AGGCGCCGTT
 GGTACCCGAC TAGGGGCTGT CGCGACTGTG GTGTGATGT GGTGCGTGA CACGGTACT GTCTTAGCAC CAACGTCCCT ACACGAGGC TCCCGGCAA
 268 GlnTrpLeu ileProAsps erAlaAspTh rThrAlaThr ProThrHisc ysAlaTyraS pArgIleVal ValAlaGlyM etLeuLeuAr gGlyAlaVal
 901 GTTCCCGACT CGGCTCTTCC CTTTAAC TTC CAGGTGCCT ATGGCCTGAG TGACCAACTG GCCCAAGCCA TCAGTGACCA CTATCCAGTG GAGGTGATGC
 CAAGGCTGA GCCGAGAAG GAAATTGAAG GTCCGACGGA TACCGGACTC ACTGGTTGAC CGGGTTCGGT AGTCACCTGGT GATAGGTAC CTCCACTACG
 301 ValProAsps erAlaLeuPr oPheAsnPhe GlnAlaAlat yriGlyLeuSe rAspGlnLeu AlaGlnAlaI leSerAspHi sTyrProVal GluValMetLeu
 1001 TGAAGTGAGC AGCCCTCTCC CACACCAAGTT GAAGTGCAG
 ACTTACTCG TCGGGGAGGG GTGTGGTCAA CTTGACGTC
 335 LysOP*Al aalaProPro HisThrSero p*ThrAla

Fig. 2.

	10	20	30	40	50
hDNase	LKIAAFNIQTFGETKMSNATLVSYIVQILSRVDIALVQEVDRDShLTAVGK				

bDNase	LKIAAFNIRTFGETKMSNATLASIVRIVRRYDIVLIEQVRDShLVAVGK				
	10	20	30	40	50
	60	70	80	90	100
hDNase	LLDNLNQDAPDTYHYVVSEPLGRNSYKERYLFVYRPDQVSAVDSYYYDDG				

bDNase	LLDYLNQDDPNTYHYVVSEPLGRNSYKERYLFLFRPNKVSVLDTYQYDDG				
	60	70	80	90	100
	110	120	130	140	150
hDNase	CEPCGNDTFNREPAIVRFFSRFTEVREFAIIVPLHAAPGDRVAEIDALYDV				

bDNase	CESCGNDSFSREPAVVKFSSHSTKVKEFAIVALHSAPSDAVAEINSLYDV				
	110	120	130	140	150
	160	170	180	190	200
hDNase	YLDVQEKWGLEdVMLMGDFNAGCSYVRPSQWSSIRLWTSPTFQWLIPDSA				

bDNase	YLDVQQKWHLNDVMLMGDFNADCSYVTSSQWSSIRLRTSSTFQWLIPDSA				
	160	170	180	190	200
	210	220	230	240	250
hDNase	DTTATPTHCAyDRIVVAGMLLRGAVVPDSALPFNFQAAYGLSDQLAQaIS				

bDNase	DTTATSTNCAYDRIVVAGSLLQSSVVGpSAAPFDfQAAYGLSNEMALaIS				
	210	220	230	240	250
	260				
hDNase	DHYPVEVMLK				

bDNase	DHYPVEVTLT				
	260				

Fig. 3.

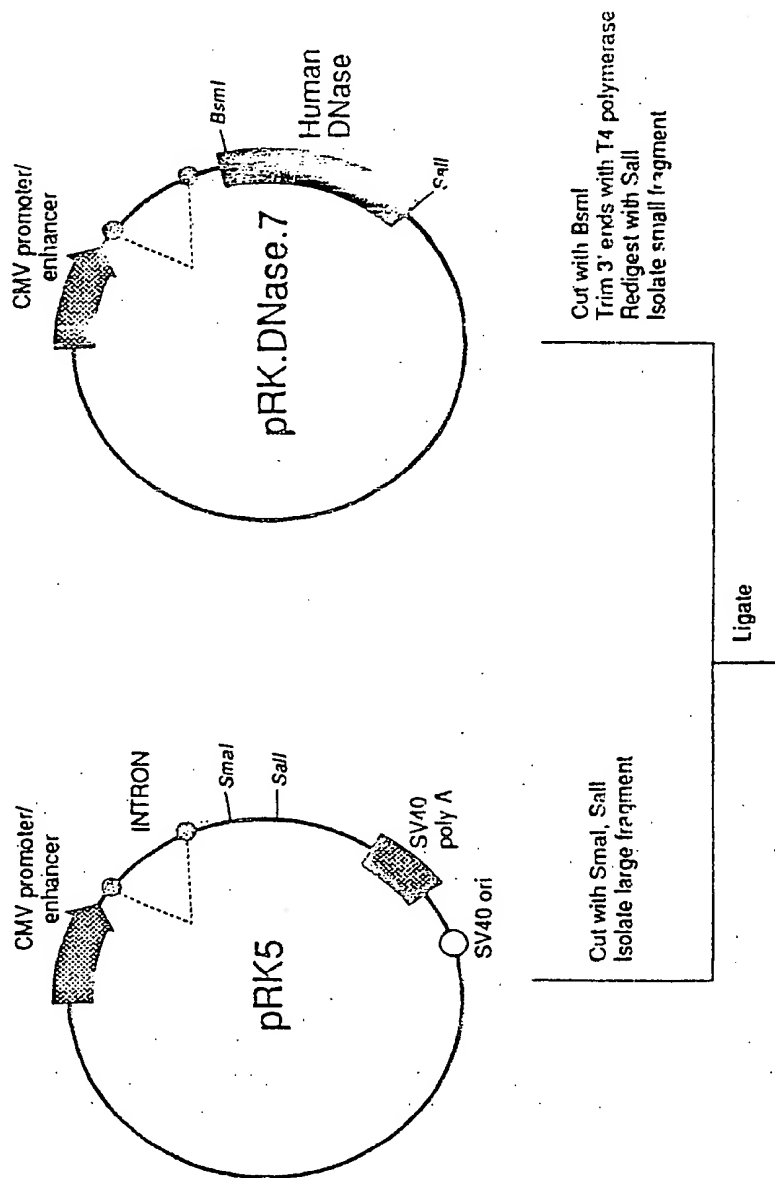


Fig. 3(cont.)

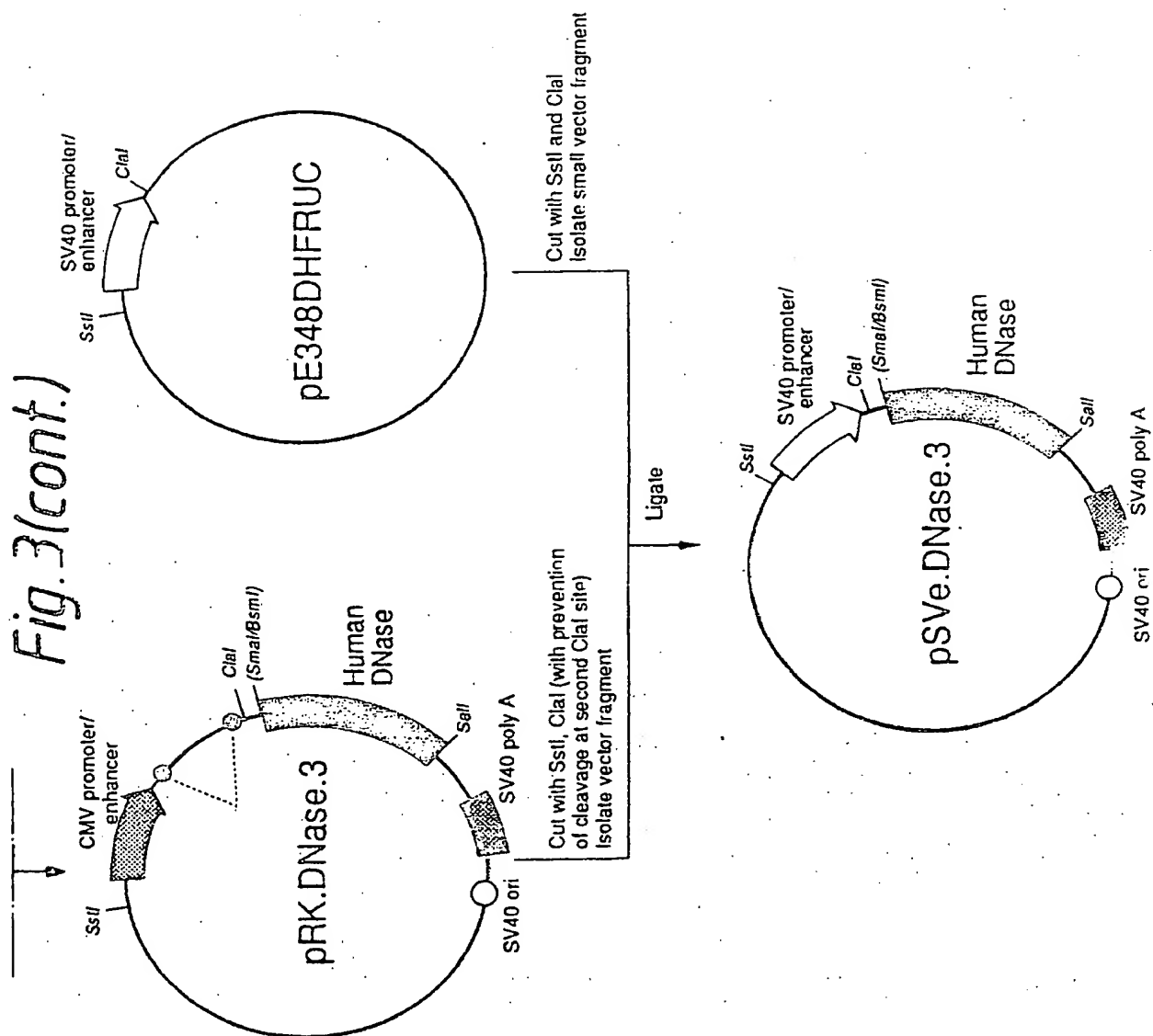


Fig. 4.

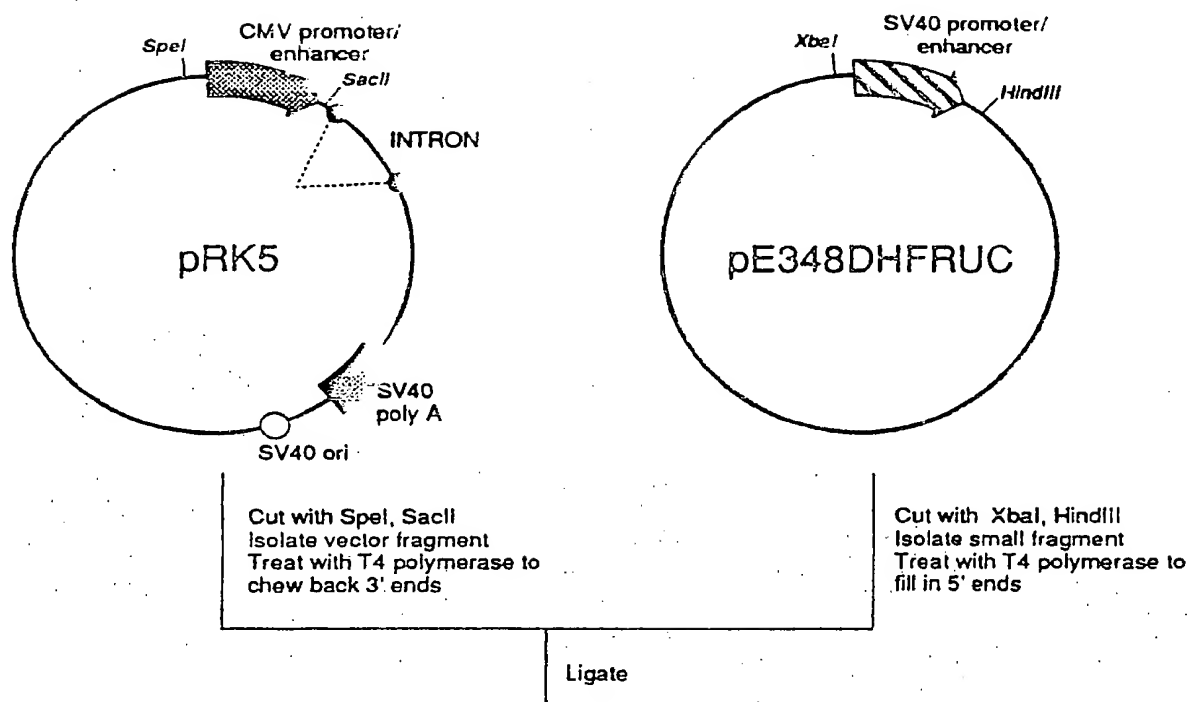


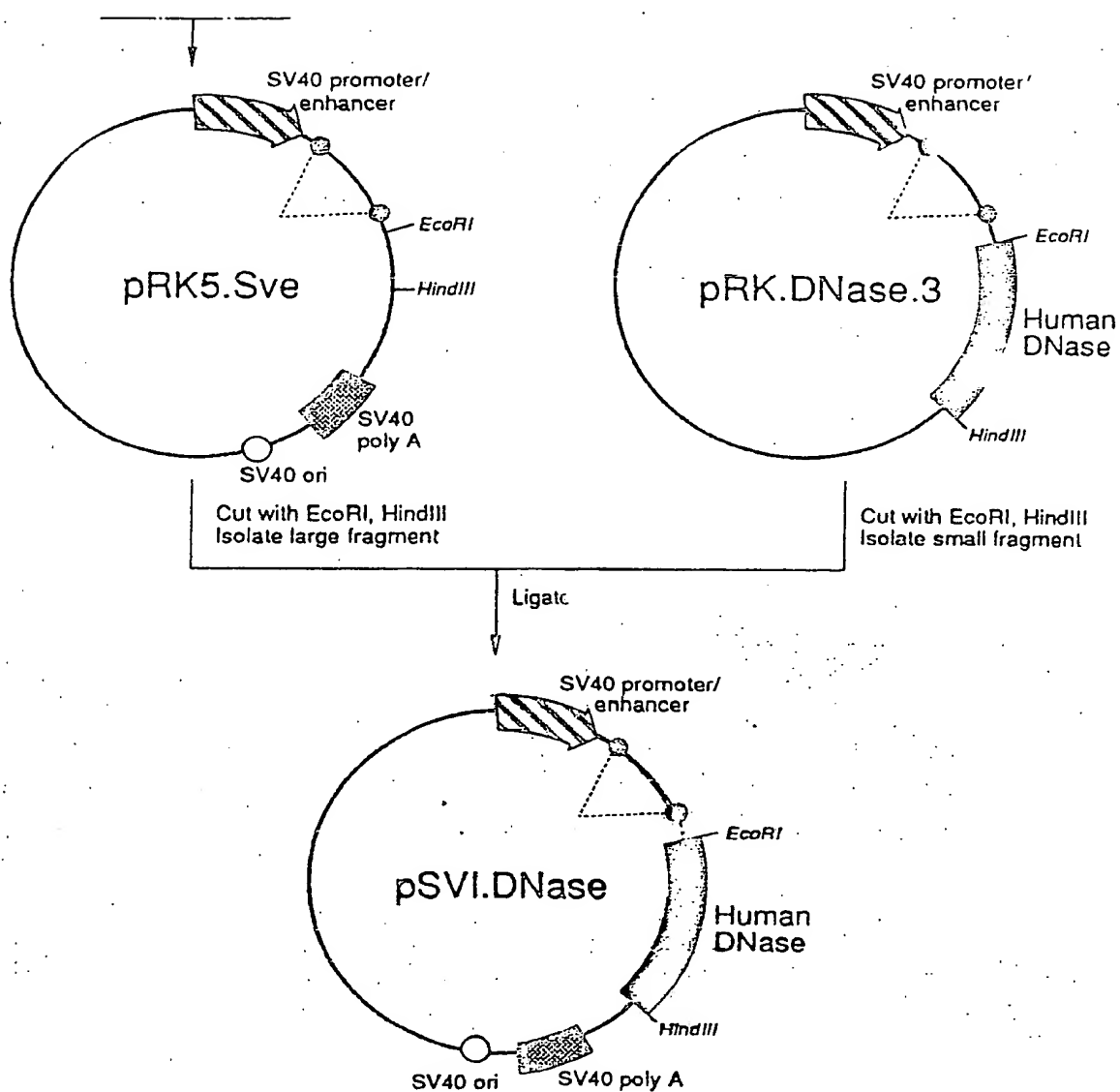
Fig. 4 (cont.)

Fig. 5.

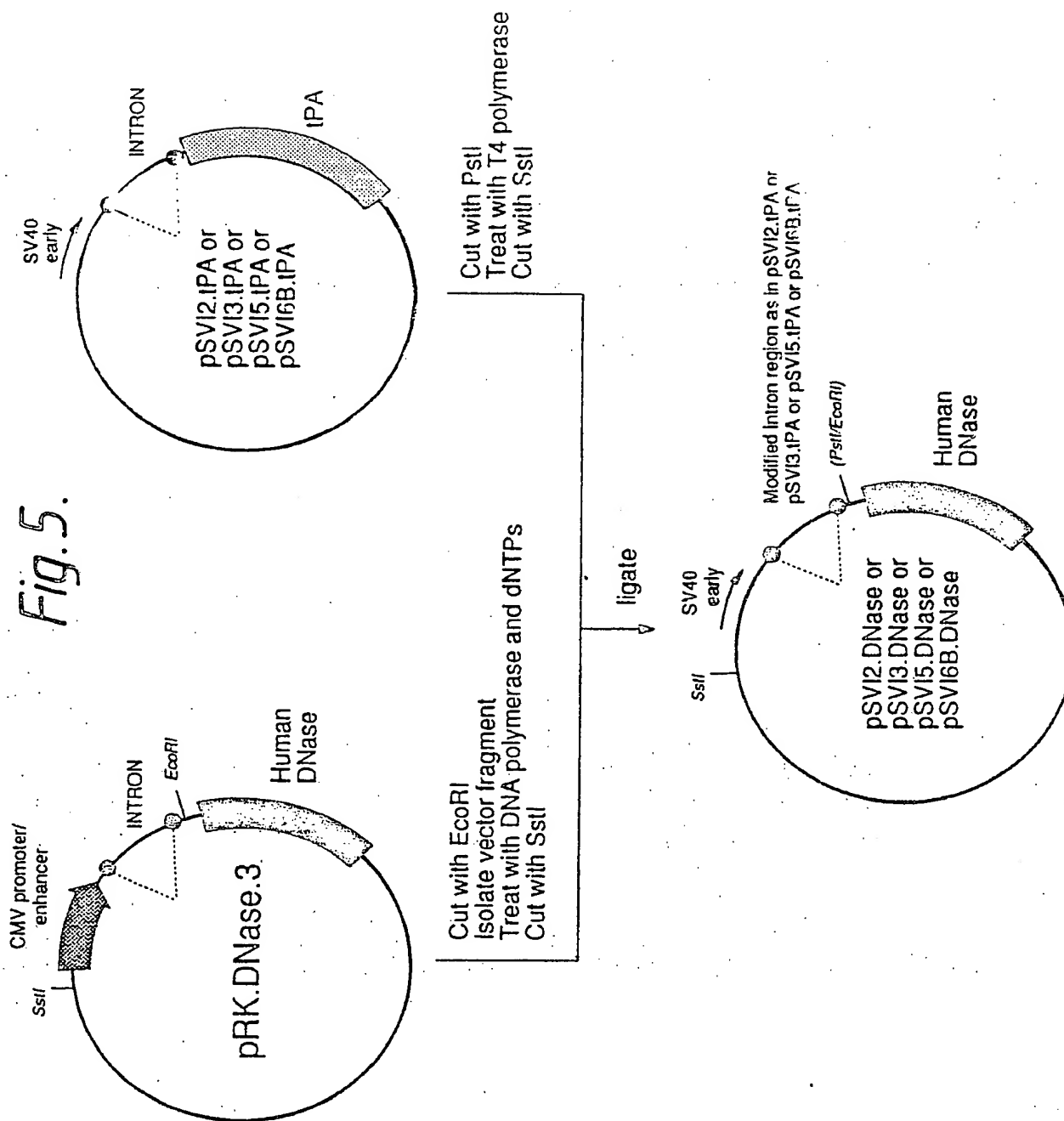


Fig. 6.

aluI
 sstI
 sacI
 hgiII
 hgiII
 bspI286
 banII
 taqI
 1 TTCGAGCTCG CCCGACATTG ATTATTGACT AGAGTCGACA GCTGTGGAAT GTCTGTCACT TAGGGTGTGG AAAGTCCCCA GGCTCCCCAG CAGGCAGGAAG
 AAGCTCGAGC GGGCTGTAC TAATAACTGA TCTCAGCTGT CGACACCTTA CACACAGTCA ATCCACACACC TTTCAGGGGT CCGAGGGGTC GTCCGCTCTTC

nlaIV
 scrFI
 ecorII
 bstNI
 nlaIV
 scrFI
 ecorII
 bstNI
 nsil
 avallI
 nlaIII
 sphi
 nspCIX
 sfanI
 nsil
 avallI
 nlaIII
 sphi
 nspCIX

101 TATGCAAGC ATGCATCTCA ATTAGTCAGC AACCAGGTGT GGAAGTCCC CAGGCTCCCC AGCAGGCAGA AGTATGCAAA GCATGCATCT CAATTAGTCA
 ATACGTTTCG TACGTAGAGT TAATCAGTCG TTGGTCCACA CCTTCAGGG GTCCGAGGGG TCGTCCGCTCT TCATACGTTT CGTACGTAGA GTTAATCAGT

nlaIII
 styI
 ncoI
 foki
 201 GCAACCATAG TCCCGCCCTT AACTCCGCC ATCCCGCC TAACTCCGCC CAGTCCGCC CATCTCCGC CCCATGGCTG ACTAATTTT TTTATTTATG
 CGTTGGTATC AGGGCGGGA TTGAGGCGG TAGGGCGGG ATTGAGCGG GTCAAGCGG GTAAGAGCG GGTACCGAC TGATTAATAA AAATAAATAC

fnu4HI
 bglI
 sfiI
 haeIII
 haeIII
 mnlI
 mnlI
 mnlI
 aluI
 301 CAGAGGCGGA GGCGGCTCG GCCTGAGC TATTCCAGAA GTAGTGAGGA GGCTTTTGT GAGGCCTAGG CTTTGTGAAA AAGCTTATCG GGCGGGGAAC
 GTCTCCGGCT CCGGCGGAGC CGGAGACTCG ATAAGGTCTT CATCACTCCT CCGAAAAAAC CTCGGGATCC GAAAACGTTT TTCGAATAGC CCGGCCCTTG

hinfI
 thal
 fnuDII
 bstUI
 rsal
 pleI
 hinfI
 bstXI
 sau96I
 haeIII
 asuI
 styI
 fnu4HI
 thal
 fnuDII
 bstUI
 asei
 sp6 promoter

401 GGTGCAATTGG AACGGGATT CCCCGTGCCA AGAGTGAGCT ATAGGCCAC CCCCTTGGCT TCGTTAGAAC GCGGCTACAA
 CCACGTAACC TTGCGCTAA GGGGACAGGT TCTCACTGCA TTCAATGCGG ATATCTCAGA TATCCGGGTG GGGGAACCGA AGCAATCTTG CCGCGATGTT

Fig.6(cont.)

```

sau96I
avaII
asul
scrFI
ecorII
bstNI

mseI      note ATG      hphI      foki      sp6 RNA start
501 TTAATACATA ACCTTATGTA TCATACACAT ACGATTTAGG TGACACTATA GAATAACATC CACTTTGCCT TTCTCTCCAC AGGTCTCCAC TCCAGGTCC
AATTATGTAT TGGAATACAT AGTATGTGTA TGCTAAATCC ACTGTGATAT CTTATTGTAG GTGAAACGGA AAGAGAGGTG TCCACAGGTG AGGTCCAGG

        bspMI
        aluI   pstI
        hindIII fnu4HI
        mnlI   ddel   bbvI      mseI   hgaI

        cloning linker
1  AACTGCACCT CGGTTCTAAG CTTGGGCTGC AGGTGCGCCGT GAATTTAAGG GACGCTGTGA AGCA
601 TTGACGTGGA GCCAAGATTC GAACCCGACG TCCACGGGCA CTTAAATTCC CTGCGACACT TCCT

```

Fig. 7.

aluI
 sstI
 sacI
 hgiIII
 hgiAI
 bsp1286
 banII
 taqI
 1 TTGAGCTCG CCCGACATTG ATTATTGACT AGAGTCGACA GCTGTGGAAT GTGTGTGCTAGT TAGGGTGTGG AAAGTCCCCA GGCTCCCCAG CAGGCAGAAAG
 AAGCTCGAGC GGGCTGTAAC TAATACTGA TCTCAGCTGT CGACACCTTA CACACAGTCA ATCCACACACC TTTCAGGGGT CCGAGGGGTC GTCCGTCTTC
 taqI
 pleI aluI
 hinfI pvuII
 nsil
 avallI
 nlaIII
 sphi sfaNI
 nspCIX
 101 TATGCAAGC ATGCATCTCA ATTAGTCAGC AACCAAGTGT GGAAGTCCC CAGGCTCCCC AGCAGGCAGA AGTATGCAAA GCATGCATCT CAATTAGTCA
 ATACGTTTCG TACGTAGAGT TAATCAGTCG TTGGTCCACA CCTTTCAGG GTCCGAGGG TCGTCCGTCT TCATACGTTT CGTACGTAGA GTTAATCAGT
 nsil
 avallI
 nlaIII
 sphi
 nspCIX
 sfaNI
 201 GCAACCATAG TCCCGCCCT AACTCCGCC ATCCCGCCC TAACTCGCC CAGTTCGCC CATTCTCCGC CCCATGGCTG ACTAATTTT TTTATTTATG
 CGTTGGTATC AGGGCGGGG TTGAGGCGGG TAGGGCGGG ATTGAGGCGG GTCAAGGCGG GTAAAGAGCG GGTACCGAC TGATTAAAAA AATAAATAC
 foki
 nlaIII
 styI
 ncoI
 scrFI
 nciI
 mspI
 hpaII
 haeIII
 xmaIII
 eagI
 eaeI
 cfrI
 301 CAGAGGCCGA GGCGCCTCG GCCTCTGAGC TATTCAGAA GTAGTGAGGA GGCTTTTTC GAGGCCTAGG CTTTGGCAAA AGCTTATCC GGCCGGGAAC
 GTCTCCGGCT CCGGCGGAGC CGGAGACTCG ATAAGGTCTT CATCACTCCT CCGAAAAAC CTCCGGATCC GAAACGTTT TTGCAATAGG CCGGCCCTTG
 fnu4HI
 bglI
 stfI
 ddeI
 haeIII haeIII haeIII mnlI mnlI aluI
 mnlI mnlI mnlI mnlI mnlI
 401 GGTGATTTGG AACGGGATT CCGCGTGGCA AGAGTCAGGT AAGTACCGCC TATAGAGTCT ATAGGCCAC CCCCTTGGCT TCGTTAGAAC GCGGTACAA
 CCAGCTAAC TTGCGCCTAA GGGGCAGGT TCTCAGTCCA TTCTATGCGG ATATCTCAGA TATCCGGTG GGGGAACCGA AGCAATCTTG CCGCCATGTT
 hinfI
 thal
 fnuDII
 bstUI
 pleI
 hinfI
 rsal
 ui matched splice donor
 10/18

Fig. 7 (cont.)

sau96I
 avaiI
 asuI
 scrFI
 ecorII
 bstNI

mseI
 hphI
 fokI
 sp6 RNA start

note ATG
 bspMI
 aluI
 pstI
 hindIII
 fnu4HI
 mnlI
 ddeI
 bbvI
 cloning linker

501 TTAATACATA ACCTTATGTA TCATACACAT ACGATTAGG TGACACTATA GAATAACATC CACTTTGCCT TTCTCTCCAC AGGTGTCCAC TCCCAGGTCC
 AATTATGTAT TGGAAATACAT AGTATGTGTA TGCTAAATCC ACTGTGATAT CTTATTGTAG GTGAACGGA AGAGAGGTG TCCACAGGTG AGGGTCCAGG

601 AACTGCACCT CGGTTCTAAG CTTGGGCTGC AGGTCGCCGT GAATTTAAGG GACGCTGTGA AGCA
 TTGACGTGGA GCCAAGATTC GAACCCGACG TCCAGCGGCA CTTAAATTCC CTGCGACACT TCGT

Fig. 8.

aluI
 sstI
 sacI
 hgiII
 hgiAI
 bsp1286
 banII
 taqI
 1 TTCGAGCTCG CCCGACATTG ATTATTGACT AGAGTCGACA GCTGTGGAAT GTCTGTCACT TAGGGTGTGG AAGTCCCCCA AGCTCCCCAG CAGGCAGGAG
 AAGCTCGAGC GGGCTGTAAC TAATAACTGA TCTCAGCTGT CGACACCTTA CACACAGTCA ATCCACACC TTTCAGGGGT CCGAGGGGTC GTCCGTCCTC
 nsII
 avallI
 nlaIII
 sphi
 nspCIX
 101 TATGCAAGC ATGCATCTCA ATTAGTCAGC AACCAAGTGT GGAAGTCCC CAGGCTCCCC AGCAGGCGA AGTAGCAAA GCATGCATCT CAATTAGTCA
 ATACGTTTCG TACGAGAGT TAATCAGTCG TTGGTCCACA CCTTCAGGG GTCCGAGGG TCGTCCGCTC TCATACGTTT CGTACGTTA GTTAATCAGT
 nsII
 avallI
 nlaIII
 sphi
 nspCIX
 201 GCAACCATAG TCCCGCCCTT AACTCCGCC ATCCCGCCCC TAACTCGCC CAGTCCGCC CATCTCCGC CCCATGGCTG ACTAATTTT TTTATTATG
 CGTTGGTATC AGGGCGGGA TTGAGGCGGG TAGGGCGGG ATTGAGGCGG GTCAAGGCGG GTAGAGGCGG GGTACCGAC TGATTAAAAA AATAAATAC
 foki
 301 CAGAGGCGGA GCGCGCTCG GCCTCTGAGC TATTCAGAA GTAGTCAGGA GGCTTTTTCG GAGGCTTAGG CTCTTGCAAA AAGCTTATCC GCGCGGGAAC
 GTCTCCGGCT CCGCGGAGC CGGAGACTCG ATAGGCTCTT CATCACTCCT CATCACTCCT CCGAAAAAC CTCCGGATCC GAACAGGTTT TTCGAATAG CCGGCCCTTG
 hinfI
 401 GGTGCAATTG AACCGGATT CCCCGTGCCA AGAGTCAGGT AAGTACCGCC TATAGAGTCT ATAGGCCAC CCCCTTGGCT TCGTTAGAAC GCGGCTACAA
 CCACGTAACC TTGCGCCTAA GGGGCACGGT TCTCAGTCCA TTGATGGCGG ATATCTCAGA TATCCGGGTG GGGGAACCGA AGCAATCTTG CCGCGATGTT
 aluI
 sstI
 sacI
 hgiII
 hgiAI
 bsp1286
 banII
 taqI
 1 TTCGAGCTCG CCCGACATTG ATTATTGACT AGAGTCGACA GCTGTGGAAT GTCTGTCACT TAGGGTGTGG AAGTCCCCCA AGCTCCCCAG CAGGCAGGAG
 AAGCTCGAGC GGGCTGTAAC TAATAACTGA TCTCAGCTGT CGACACCTTA CACACAGTCA ATCCACACC TTTCAGGGGT CCGAGGGGTC GTCCGTCCTC
 nsII
 avallI
 nlaIII
 sphi
 nspCIX
 101 TATGCAAGC ATGCATCTCA ATTAGTCAGC AACCAAGTGT GGAAGTCCC CAGGCTCCCC AGCAGGCGA AGTAGCAAA GCATGCATCT CAATTAGTCA
 ATACGTTTCG TACGAGAGT TAATCAGTCG TTGGTCCACA CCTTCAGGG GTCCGAGGG TCGTCCGCTC TCATACGTTT CGTACGTTA GTTAATCAGT
 nsII
 avallI
 nlaIII
 sphi
 nspCIX
 201 GCAACCATAG TCCCGCCCTT AACTCCGCC ATCCCGCCCC TAACTCGCC CAGTCCGCC CATCTCCGC CCCATGGCTG ACTAATTTT TTTATTATG
 CGTTGGTATC AGGGCGGGA TTGAGGCGGG TAGGGCGGG ATTGAGGCGG GTCAAGGCGG GTAGAGGCGG GGTACCGAC TGATTAAAAA AATAAATAC
 foki
 301 CAGAGGCGGA GCGCGCTCG GCCTCTGAGC TATTCAGAA GTAGTCAGGA GGCTTTTTCG GAGGCTTAGG CTCTTGCAAA AAGCTTATCC GCGCGGGAAC
 GTCTCCGGCT CCGCGGAGC CGGAGACTCG ATAGGCTCTT CATCACTCCT CATCACTCCT CCGAAAAAC CTCCGGATCC GAACAGGTTT TTCGAATAG CCGGCCCTTG
 hinfI
 401 GGTGCAATTG AACCGGATT CCCCGTGCCA AGAGTCAGGT AAGTACCGCC TATAGAGTCT ATAGGCCAC CCCCTTGGCT TCGTTAGAAC GCGGCTACAA
 CCACGTAACC TTGCGCCTAA GGGGCACGGT TCTCAGTCCA TTGATGGCGG ATATCTCAGA TATCCGGGTG GGGGAACCGA AGCAATCTTG CCGCGATGTT

13/18

Fig. 8(cont.)

sau3AI
 mboI
 dpnI
 alwI
 xhoII
 nlaIV
 bstYI
 bamHI
 mseI
 removed ATG
 lariat consensus
 501 TTAATACATA ACCTTTTGGG TCCTATAGAC TGACATCCAC TTTGCCTTTC TCCTCCACAGG TGCTCCACTCC CAGGTCCCAAC TGCACCTCGG TTCGAAGCTT
 AATTATGTAT TGGAAACCT AGGATATCTG ACTGTAGGTG AAACGGAAG AGAGGTGTCC ACAGGTGAGG GTCCAGGTTG ACGTGGAGCC AAGCTTCGAA
 foki
 bspMI
 pstI
 fnu4HI
 bbvI
 mseI hgaI
 601 GGGCTGCAGG TCGCCGTGAA TTTAAGGGAC GCTGTGAAGC A
 CCCGACGTCC AGCGGCACCT AAATTCCCTG CGACACTTCG T

sau96I
 avaiI
 asuI
 scrFI
 ecorII
 bstNI
 aluI
 hindIII
 tagI
 bstBI
 asuII
 mnII
 cloning linker

Fig. 9.

14/18

```

    aluI
    sstI
    sacI
    hgiJII
    hgiAI
    bsp1286
    banII
    taqI
1  TTCGAGCTCG CCCGACATTG ATTATTGACT AGAGTCGACA GCTGTGGAAT GTGTGTCAGT
   AAGCTCGAGC GGGCTGTAAC TAATAACTGA TCTCAGCTGT CGACACCTTA CACACAGTCA

                                nlaIV
                                scrFI
                                ecorII
                                bstNI
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   ATCCCACACC TTTCAGGGGT CCGAGGGGTC GTCCGTCTTC ATACGTTTCG TACGTAGAGT

                                nlaIV
                                scrFI
                                ecorII
                                bstNI
121 ATTAGTCAGC AACCAGGTGT GGAAAGTCCC CAGGCTCCCC AGCAGGCAGA AGTATGCAAA
   TAATCAGTCG TTGGTCCACA CCTTTCAGGG GTCCGAGGGG TCGTCCGTCT TCATACGTTT

    sfaNI
    nsII
    avaIII
    nlaIII
    sphI
    nspCIX
181 GCATGCATCT CAATTAGTCA GCAACCATAG TCCCGCCCCCT AACTCCGCCC ATCCCGCCCC
   CGTACGTAGA GTTAATCAGT CGTTGGTATC AGGGCGGGGA TTGAGGCGGG TAGGGCGGGG

                                nlaIII
                                styI
                                ncoI
241 TAACTCCGCC CAGTTCGCC CATTCTCCGC CCCATGGCTG ACTAATTTT TTTATTTATG
   ATTGAGGCGG GTCAAGGCGG GTAAGAGGCG GGGTACCGAC TGATTAAAAA AAATAAATAC

    fnu4HI
    bglI
    sfiI
    ddeI
    haeIII haeIII haeIII
    mnlI mnlI mnlI mnlI aluI
301 CAGAGGCCGA GGCCGCCTCG GCCTCTGAGC TATTCCAGAA GTAGTGAGGA GGCTTTTTTG
   GTCTCCGGCT CCGGCGGAGC CGGAGACTCG ATAAGGTCTT CATCACTCCT CCGAAAAAAC

                                scrFI
                                nciI
                                mspI
                                hpaII
                                haeIII
                                xmaIII
                                eagI
                                eaeI
                                cfrI
                                aluI mspI cauII
                                hindIII hpaII
361 GAGGCCTAGG CTTTTGCAAA AAGCTTATCC GGCCGGAAC GGTGCATTGG AACGCGGATT
   CTCCGGATCC GAAAACGTTT TTCGAATAGG CCGGCCCTTG CCACGTAACC TTGCGCCTAA

                                bstXI
                                sau96I
                                haeIII
                                asuI
                                styI
                                pleI
                                hinfI
                                rsaI
                                U1 matched splice donar
421 CCCCCTGCCA AGAGTCAGGT AAGTACCGCC TATAGAGTCT ATAGGCCAC CCCCTTGGCT
   GGGGCACGGT TCTCAGTCCA TTCATGGCGG ATATCTCAGA TATCCGGGTG GGGGAACCGA

```

Fig. 9(cont.)

sau3AI
 mboI
 dpnI
 alwI
 xhoII
 nlaIV
 bstXI
 bamHI
 alwI
 removed ATG
 U2 match lariat consensus
 481 TCGTTAGAAC GCGGCTACAA TTAATACATA ACCTTTTGGG TCTACTAAC TACTGACTTA
 AGCAATCTTG CGCCGATGTT AATTATGTAT TGGAAAACCT AGGATGATTG ATGACTGAAT

fnu4HI
 thaI
 fnuDII
 bstUI
 sp6 promoter
 mseI
 aseI

sau96I
 avall
 asuI
 scrFI
 ecorII
 bstNI
 thaI
 fnuDII
 bstUI
 mnlI
 nruI
 hindIII
 cloning linker
 541 TTCTTTTCCCT TTCTCTCCAC AGGTGTCCAC TCCACAGGTG AGGTCCAGG TCGACGTGGA GCCAAGCGCT
 AAGAAAAGGA AAGAGAGGTG TCCACAGGTG AGGTCCAGG TCGACGTGGA GCCAAGCGCT

bspMI
 pstI
 fnu4HI
 aluI
 bbvI
 mseI
 hgaI
 1
 601 AGCTTGGGCT GCAGGTGCGC GTGAATTAA GGGACGCTGT GAAGCA
 TCGAACCGCA CGTCCAGCGG CACTTAAATT CCTGCGACA CTTTCGT

Fig. 10.

aluI
 sstI
 sacI
 hgiIII
 hgiAI
 bsp1286
 banII
 taqI
 1 TTCGAGCTCG CCCGACATTG ATTATTGACT AGAGTCGACA GCTGTGGAAT GTGTGTGAGT TAGGGTGTGG AAAGTCCCCA GGCTCCCCAG CAGGCAGAAG
 AAGCTCGAGC GGGCTGTAAAC TAATAACTGA TCTCAGCTGT CGACACCTTA CACACAGTCA ATCCCCACACC TTTCAGGGGT CCGAGGGGTC GTCCGCTCTTC
 nsII
 avaIII
 nlaIII
 sphi
 nsCIX
 sfaNI
 nsII
 avaIII
 nlaIII
 sphi
 nsCIX
 101 TATGCAAGC ATGCATCTCA ATTAGTCAGC AACAGGCTGT GGAAGTCCC CAGGCTCCCC AGCAGGAGAGA AGTATGCAAA GCATGCATCT CAATTAGTCA
 ATACGTTTCG TACGTAGAGT TAATCAGTCG TTGCTCCACA CTTTCAGGG GTCCGAGGG TCGTCCGCTCT TCATACGTTT CGTACGTAGA GTTAATCAGT
 nlaIII
 styI
 ncoI
 201 GCAACCATAG TCCCGCCCT AACTCCGCC ATCCGCCCC TAACTCCGCC CAGTTCGCC CATTCTCCGC CCCATGGCTG ACFAATTTT TTTATTTATG
 CGTTGGTATC AGGGCGGGA TTGAGGCGGG TAGGCGGGG ATTGAGGCGG GTCAAGGCGG GTAAGAGGCG GGTACCGAC TGATAAATAA AATAAATAAC
 foki
 bsrI
 styI
 avrII
 haeIII
 stuI
 haeI
 mnlI
 mnlI
 mnlI
 aluI
 mspi
 cauII
 hindIII
 hpaII
 301 .CAGAGGCCGA GGCGCCTCG GCCTCTGAGC TATTCAGAA GTACTGAGGA GGCTTTTGTG GAGGCCTAGG CTTTGGCAAA AGCTTATCC GGCGGGGAAC
 GTCTCCGGCT CCGCGGAGC CGGAGACTCG ATAAGTCTT CATCACTCCT CCGAAAAAC CTCCGGATCC GAAAAAGTTT TTCGAATAGG CCGGCCCTTG
 fnu4HI
 bglI
 sfiI
 ddeI
 haeIII
 haeIII
 mnlI
 mnlI
 aluI
 mnlI
 mnlI
 aluI
 mspi
 cauII
 hindIII
 hpaII
 401 GGTGCAATTG AACGCGGATT CCCCGTGCCA AGAGTCAGGT AAGTACCGC TATAGAGTCT ATAGGCCAC CCCCTTGGCT TCGTTAGAAC GCGGCTACAA
 CCACGTAACC TTGCGCCTAA GGGGCACGCT TCTCAGTCCA TTCTATGCGG ATATCTCAGA TATCCGGGTG GGGGAACCGA AGCAATCTTG CCGCGATGTT
 hinfi
 thai
 fnuDII
 bstUI
 pleI
 hinfi
 rsal
 ui
 matched
 splice
 donar
 pleI
 hinfi
 bstUI
 styI
 sp6 promoter
 asei
 fnu4HI
 thai
 fnuDII
 bstUI
 asei

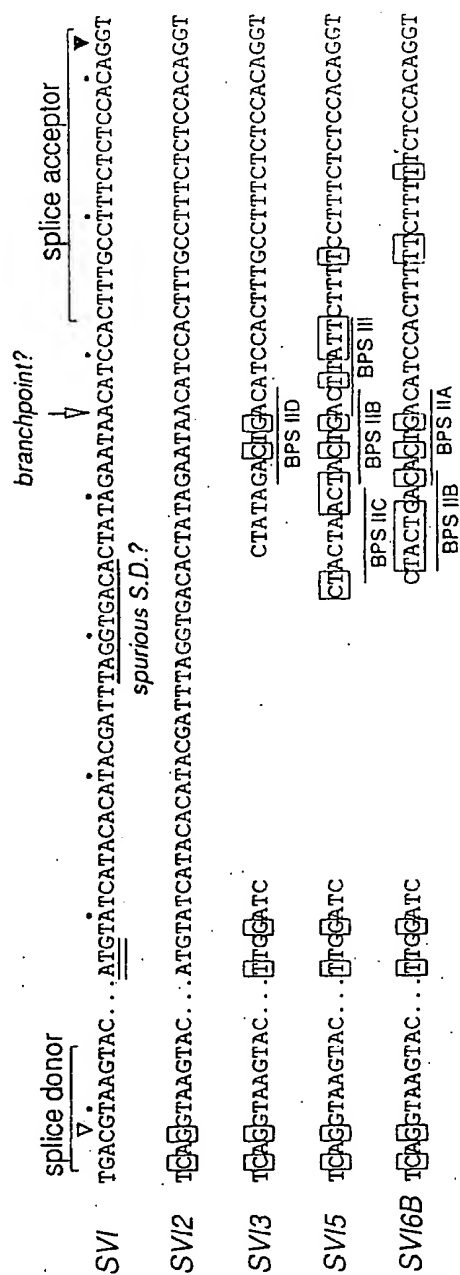
Fig. 10(cont.)

```

sau3AI
mboI
dpmI
alwI
xhoII
nlaIV
bstYI
bamHI
alwI
removed ATG
mseI
fokI
sau96I
avaII
asul
scrFJ
ecorII
bstNI
mnII
nruI hindIII
thai aluI
fndDII
bstII
nruI hindIII
lariat consensus
IgG vH natural lariat restored
501 TTAATACATA ACCTTTTGA TCCTACTGAC ACTGACATCC ACTTTTCTT TTTCTCCACA GGTGTCCACT CCCAGGTCCA ACTGCACCTC GGTTCGCCAA
AATTATGTAT TGGAAACCT AGGATGACTG TGAAGTAGG TGAAGAGAA AAGAGGTGT CCACAGGTGA GGTCCAGGT TGCCTGGAG CCAAGCGCTT
cloning linker
601 GCCTGGGCTG CAGGTGCGCG TGAATTTAAG GGACGCTGTG AAGCA
CGAACCCGAC GTCAGCGGC ACTTAATTC CCTGCGACAC TTCGT

```

Fig. 11.



INTERNATIONAL SEARCH REPORT

International Application No. **PCT/US 89/05744**

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) *

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: C 12 N 9/16, C 12 N 15/55

II. FIELDS SEARCHED

Minimum Documentation Searched *

Classification System

Classification Symbols

IPC5

C 12 N

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched *

III. DOCUMENTS CONSIDERED TO BE RELEVANT *

Category *	Citation of Document, ** with indication, where appropriate, of the relevant passages **	Relevant to Claim No. **
X	Chemical Abstracts, volume 88, no. 7, 13 February 1978, (Columbus, Ohio, US), Funakoshi, Akihiro et al : "Purification and properties of human pancreatic deoxyribonuclease I ", see page 217, abstract 46840u, & J. Biochem. 1977, 82(6), 1771-1777	1-4,6-19,23
Y	--	20-21, 24-35
X	Chemical Abstracts, volume 110, no. 1, 2 January 1989, (Columbus, Ohio, US), Rosenstreich, David L et al : "A human urine-derived interleukin 1 inhibitor. Homology with deoxyribonuclease I ", see page 564, abstract 5954p, & J.Exp.Med. 1988, 168(5), 1767-1779	1-4,6-19,23
Y	--	20-21, 24-35

* Special categories of cited documents: **

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

3rd April 1990

Date of Mailing of this International Search Report

19 APR 1990

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

MISS D. S. KOWALCZYK

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	Patent Abstracts of Japan, Vol 5, No 4, C 38, abstract of JP 55-131389, publ 1980-10-13 (AMANO SEIYAKU K.K.)	1-4,6- 19,23
Y	--	20-21, 24-35
X	J. Biochem., Vol. 95, 1984, Kazuo Ito et al: "Human Urine DNase I: Immunological Identity with Human Pancreatic DNase I, and Enzymic and Proteochemical Properties of the Enzyme ", see page 1399 - page 1406	1-4,6- 19,23
Y	--	20-21, 24-35
X	J. Biochem., Vol. 87, 1980, Koichiro Murai et al: "Purification and Properties of Deoxyribonuclease II from Human Urine ", see page 1097 - page 1103	1-4,6- 19,23
Y	--	20-21, 24-35
Y	Eur. J. Biochem., Vol. 179, 1989, Bradley Nefsky et al: "Preparation of immobilized monomeric actin and its use in the isolation of protease-free and ribonuclease-free pancreatic deoxyribonuclease I ", see page 215 - page 219	20
A	Biochemical society transactions, Vol. 16, 1988, Denise Shields et al: "Cloning of part of the gene for bovine deoxyribonuclease I ", see page 195 - page 196	6-11
Y	Susan Budavari et al "The Merck Index, eleventh edition", 1989, Merck & Co., Inc., USA, see page 2890 no. 2888, "Deoxyribonuclease (Pancreatic)"	28-35

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
Y	John E. Hoover "Remington's Pharmaceutical Sciences", 1975, Mack Publishing Company, Pennsylvania, see page 972- page 973 "Pancreatic Dornase for Sterile Solution"	28-35
